INTERIM REPORT

REGIONAL APPLIED RESEARCH (RARE) PROJECT: INTERIM REPORT FOR INVESTIGATION OF CHANGES IN LEAD RELATIVE BIOAVAILABILITY FOLLOWING WEATHERING OF ORE CONCENTRATE-SOIL MIXTURES FROM THE HERCULANEUM, MISSOURI, SMELTER SITE

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NOTICE

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threatens human health and the environment. The focus of the Laboratory's research program is on methods and their cost effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments, and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. The NRMRL collaborates with both public and private-sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

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EXECUTIVE SUMMARY

A study using juvenile swine as test animals was performed by Casteel et al. (2006) to measure the gastrointestinal absorption of lead from a test soil collected from the Herculaneum Lead Smelter Site in Herculaneum, Missouri. The test soil, designated "HER-2930," was collected from the Herculaneum Lead Smelter test plot and contained an acid extractable lead concentration of 2021 μg/g. The relative bioavailability of lead in the test soil was assessed by comparing the absorption of lead from the test soil to that of a reference material (lead acetate).

Groups of five swine were given oral doses of lead acetate or the test soil twice a day for 15 days. The amount of lead absorbed by each animal was evaluated by measuring the amount of lead in the blood (measured on days 0, 1, 2, 3, 5, 7, 9, 12, and 15) and the amount of lead in liver, kidney, and bone (measured on day 15 at study termination). The amount of lead present in blood or tissues of animals exposed to test soil was compared to that for animals exposed to lead acetate, and the results were expressed as relative bioavailability (RBA). The RBA results for the test soil in this study are summarized below:

Measurement Endpoint	Estimated Soil RBA (90% Confidence Interval)
Blood Lead AUC*	0.75 (0 62 – 0.93)
Liver Lead	1 01 (0 76 – 1.34)
Kidney Lead	0.84 (0.69 – 1.04)
Femur Lead	0 69 (0.61 – 0.79)
Point Estimate	0 82 (0 63 – 1 15)

*Blood AUC data were fit to the linear model

As seen, using lead acetate as a relative frame of reference, the RBA estimate is approximately 82% for the test soil. This relative bioavailability estimate may be used to improve accuracy and decrease uncertainty in estimating human health risks from exposure to this test soil.

A split of this same soil material was used by Drexler (2005) for in vitro bioaccessibility determination at the University of Colorado's Laboratory for Environmental and Geological Studies. The mean ± 1 standard deviation for triplicate analysis was 0.687 ± 0.015. Interpolation of this value into Figure 3-6 of USEPA (2004a) yields a "best estimate" of 66.6% RBA and a 95% UCL of 89.9%.

Given the results for the preliminary geochemical modeling (Section 5), plus above analytical data, MSE Technology Applications, Inc. suggests that an RBA in the 65%-75% range appears reasonable for the 12-month soil sample. Such exceedance of the integrated exposure uptake biokinetic (IEUBK) model default RBA value (0.60) may be due to: 1) initial conversion of the small (< 2 μm) galena particles to pyromorphite, followed by 2) surface oxidation of the pyromorphite particles to such biologically available forms of Pb as cerussite.

CONTENTS

FIGURES

Page

TABLES

ACRONYMS

AA	atomic absorption
ABA	absolute bioavailability
AFo	oral absorption fraction
AUC	area under the curve
BAF	bioaccessible fraction
CDCP	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EDTA	ethylenediaminetetra-acetic acid
EPA	U.S. Environmental Protection Agency
IAG	Interagency Agreement
ICP	inductively coupled plasma
ICP-AES	inductively coupled plasma atomic emission spectrography
ID	identification
IVBA	in vitro bioaccessibility
kg	kilogram
µg/g	micrograms per gram
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
MSE	MSE Technology Applications, Inc.
ng/mg	nanogram per milligram
ng/mL	nanogram per milliter
NIST	National Institute of Standards and Testing
NRMRL	National Risk Management Research Laboratory
Pb	lead
ppm	parts per million
QA	quality assurance
QAPP	quality assurance project plan
RARE	Regional Applied Research Effort
RBA	relative bioavailability
RPD	relative percent difference
SOP	standard operating procedure
SRM	Standard Reference Material
TCLP	Toxicity Characteristic Leaching Procedure
TSA	technical systems audit
UM/VMDL	University of Missouri Veterinary Medical Diagnostic Laboratory

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- Dr. John Yang (Lincoln University of Missouri) for timely preparation, analysis, and shipping of the test materials;
- Dr. Stan Casteel (University of Missouri) and Dr. Bill Brattin (Syracuse Research Corp.) for their performance and statistical analysis, respectively, of the swine dosing study;
- Dr. John Drexler (University of Colorado) for performing the in vitro (bioaccessibility) study; and
- EPA Mine Waste Technology Program and Region 7 personnel for background technical and administrative support.

1. INTRODUCTION

1.1 PROJECT BACKGROUND

EPA Region VII is the location of one of the largest historic lead (Pb) mining and smelting areas in the nation, if not the world. Lead mining activities in Region VII occurred in a broad band more than 50 miles wide stretching from St. Louis, Missouri southwestward into southeastern Kansas. More than 3,000 historic mine sites and over 130 primary smelters have been identified in Missouri alone. Approximately 20 smelters were located in southeastern Kansas, and one of the largest secondary Pb smelters in the nation was located in Omaha, Nebraska. Many of these mines and smelters are located in populated areas, and present a significant health risk to people.

The Herculaneum Lead Smelter site in Herculaneum, Missouri contains the largest active Pb smelter of its kind in the United States. The site consists of three main areas: the smelter plant, the slag storage pile, and office buildings. The site encompasses approximately 52 acres. It is bordered on the east by the Mississippi River and on the north and west by residential areas. The Herculaneum Lead Smelter site is owned by Doe Run Company (Figure 1-1).

In September 2001, Pb ore concentrate, also referred to as milled ore, was discovered on the streets of Herculaneum. Extensive removal actions were initiated in the fall of 2001 and remain ongoing. Residential yard soil replacement, home interior cleaning, street cleaning, and significant changes to concentrate handling procedures have been implemented.

Lead ore concentrate is a Pb production intermediary that is processed at milling facilities and subsequently trucked to smelting facilities where it is processed into pure Pb product. Concentrate is a fine-grained, powder-like material that consists of 70% Pb. Government regulators discovered that copious amounts of Pb concentrate were being spilled from trucks and/or being tracked out of the storage areas at the Doe Run smelter facility and spreading to the yards in Herculaneum.

Although the Doe Run Company has conducted most of the removal actions at the site to date, EPA has incurred significant oversight and monitoring expenditures. Doe Run is contending that Pb ore concentrate has an extremely low bioavailability potential and therefore, presents a minimal public health threat. EPA has maintained that Pb in the form of mill concentrate can readily oxidize and become more bioavailable over time when exposed to the environment. Presently, EPA is not aware of any specific studies that have quantified the bioavailability of Pb ore concentrate after being exposed to the environment.

The amount of Pb absorption by the body when ingested is referred to as "bioavailability". Each of the 240 different mineralogical species of Pb has a different bioavailability depending on the elements combined with the Pb in the individual species or mineral. Measuring the relative bioavailability (RBA) of Pb in soil is accomplished using an EPA Immature Swine Study (in vivo bioavailability analysis), where young weanling swine are dosed with either the test soil containing a known quantity of Pb or the control soil containing the equivalent concentration of Pb, but essentially in a 100% bioavailable form. Blood, venous blood, soft tissue, and bone samples are obtained to measure the respective adsorption rates of the test and reference Pb compounds into the exposed swine. The tissue-specific differences in Pb concentrations in these two exposure groups are used to calculate the overall Pb-RBA of the particular test soil (Casteel et al., 1996).

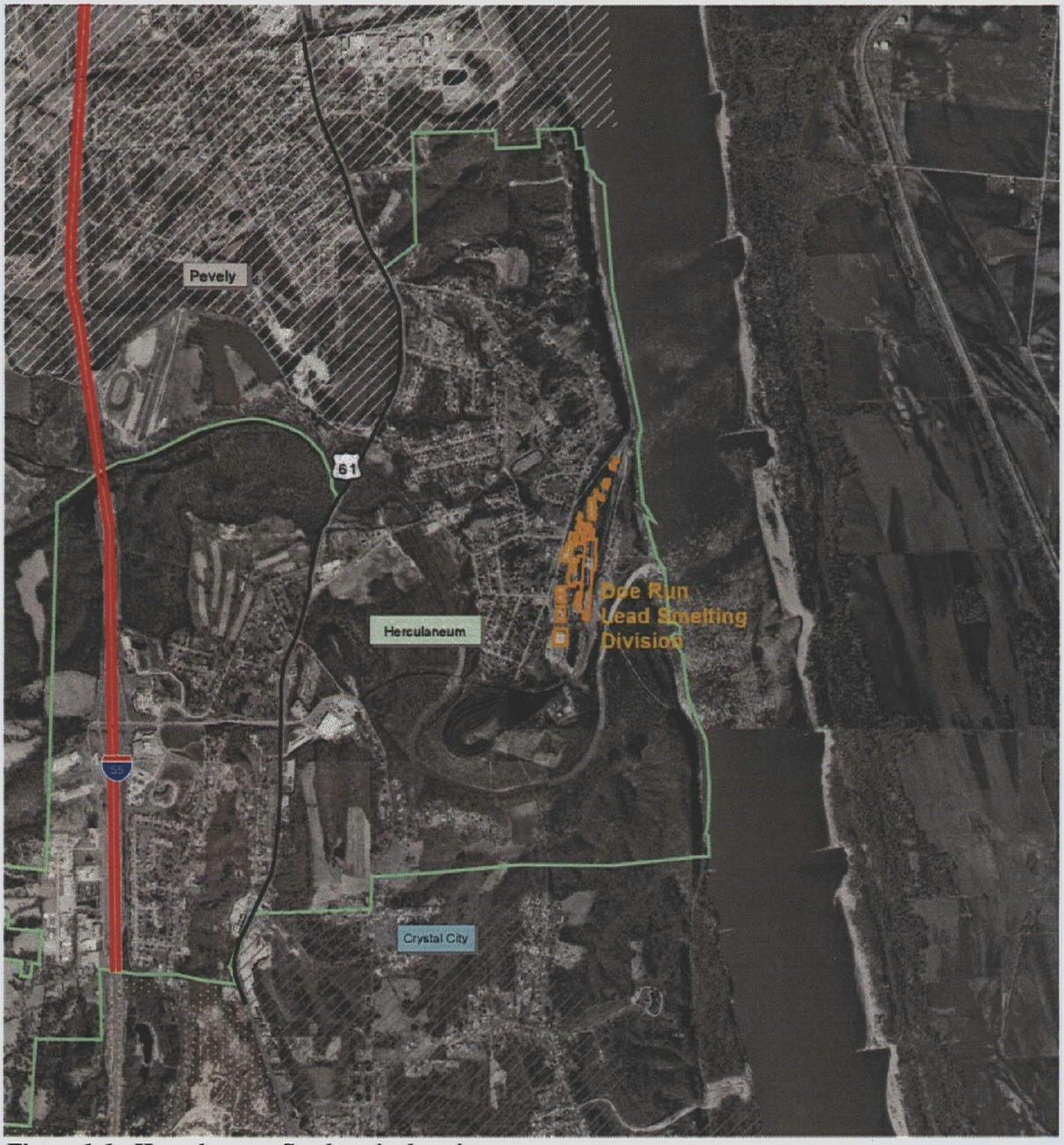


Figure 1-1. Herculaneum Smelter site location map.

In vitro methods that simulate Pb behavior in mammalian gastrointestinal tracts have also been developed over the past 10 years (e.g., Ruby et al., 1999). Such approach to estimating Pb bioaccessibility is attractive as it is less time- and money-consuming than swine feeding studies. Furthermore, previous (site-specific) investigations that employed both in vitro and in vivo approaches show promising correlations between the two types of results (USEPA, 2004a). Consequently, this dual-approach was used in the Herculaneum ore concentrate-soil weathering study.

1.2 PROJECT GOALS AND OBJECTIVES

This study will document changes in the relative bioavailability and in vitro bioaccessibility (IVBA) of Pb in ore concentrate-soil mixtures allowed to weather in test plots established in the Herculaneum area. Representative samples of soils will be collected after 12 and 24 months of environmental exposure. The dried, sieved (< 250 μm) materials will be used for the time-specific determinations of relative bioavailability (RBA) and IVBA. This interim report presents the results from the sample weathered for 12 months.

Dr. Stan Casteel of the University of Missouri (Columbia), Veterinary Medical Diagnostic Laboratory (UM/VMDL) was the Principal Investigator for the in vivo Pb bioavailability studies that dosed young swine with lead ore concentrate from the field test plots at Herculaneum. Sections of this report discussing the in vivo bioavailability are taken verbatim from Casteel et al. (2006). Physicochemical characterization of the samples was performed by Dr. John Yang at Lincoln University of Missouri (Jefferson City, Missouri). The in vitro Pb bioaccessibility extractions and subsequent chemical analyses were performed by Dr. John Drexler of the University of Colorado (Boulder). His data is found in Appendix B of this report. Quality assurance oversight, as well as general review and interpretation of all available data were performed by MSE.

1.3 OVERVIEW OF BIOAVAILABILITY

Reliable analysis of the potential hazard to humans from ingestion of lead depends upon accurate information on a number of key parameters, including lead concentration in environmental media (e.g., soil, dust, water, food, air, paint), intake rates of each medium, and the rate and extent of lead absorption by the body from an ingested medium ("bioavailability"). Knowledge of lead bioavailability is important because the amount of lead that actually enters the body from an ingested medium depends on the physical-chemical properties of the lead and of the medium. For example, lead in soil may exist, at least in part, as poorly water-soluble minerals, and may also exist inside particles of inert matrix such as rock or slag of variable size, shape, and association; these chemical and physical properties may influence the absorption (bioavailability) of lead when ingested. Thus, equal ingested doses of different forms of lead in different media may not be of equal health concern.

Bioavailability is normally described as the fraction or percentage of a chemical that is absorbed by the body following an exposure of some specified amount, duration, and route (usually oral). Bioavailability of lead in a particular medium may be expressed either in absolute terms (absolute bioavailability) or in relative terms (relative bioavailability). Absolute bioavailability (ABA) is the ratio of the amount of lead absorbed compared to the amount ingested:

$$ABA = (\text{Absorbed Dose}) / (\text{Ingested Dose})$$

This ratio is also referred to as the oral absorption fraction (AFo). Relative bioavailability is the ratio of the absolute bioavailability of lead present in some test material compared the absolute bioavailability of lead in some appropriate reference material:

$$RBA = ABA(\text{test}) / ABA(\text{reference})$$

Usually the form of lead used as reference material is a soluble compound such as lead acetate that is expected to completely dissolve when ingested.

For example, if 100 micrograms (μg) of lead dissolved in drinking water were ingested and a total of 50 μg entered the body, the ABA would be 50/100, or 0.50 (50%). Likewise, if 100 μg of lead contained in soil were ingested and 30 μg entered the body, the ABA for soil would be 30/100, or 0.30 (30%). If the lead dissolved in water were used as the frame of reference for describing the relative amount of lead absorbed from soil, the RBA would be 0.30/0.50, or 0.60 (60%).

For additional discussion about the concept and application of bioavailability, see Gibaldi and Perrier (1982), Goodman et al. (1990), Mushak (1991), and/or Klaassen et al. (1996).

1.4 USING BIOAVAILABILITY DATA TO IMPROVE EXPOSURE CALCULATIONS FOR LEAD

When reliable data are available on the bioavailability of lead in soil, dust, or other soil-like waste materials at a site, this information can be used to improve the accuracy of exposure and risk calculations at that site. For example, the basic equation for estimating the site-specific ABA of a test soil is as follows:

$$ABA_{soil} = ABA_{soluble} \cdot RBA_{soil}$$

where:

ABA_{soil}	=	Absolute bioavailability of lead in soil ingested by a human
$ABA_{soluble}$	=	Absolute bioavailability in children of some dissolved or fully soluble form of lead
RBA_{soil}	=	Relative bioavailability of lead in soil as measured in swine

Based on available information on lead absorption in humans and animals, the U.S. Environmental Protection Agency (USEPA) estimates that the absolute bioavailability of lead from water and other fully soluble forms of lead is usually about 50% in children (USEPA, 1991) and about 20% in adults (USEPA, 2003). Thus, when a reliable site-specific RBA value for soil is available, it may be used to estimate a site-specific absolute bioavailability in that soil, as follows:

$$ABA_{soil}\ (child) = 50\% \cdot RBA_{soil}$$
$$ABA_{soil}\ (adult) = 20\% \cdot RBA_{soil}$$

The default RBA used by USEPA for lead in soil and dust compared to lead in water is 60% for both children and adults. When the measured RBA in soil or dust at a site is found to be less than 60% compared to some fully soluble form of lead, it may be concluded that exposures to and hazards from lead in these media at that site are probably lower than the typical default assumptions. If the measured RBA is higher than 60%, absorption of and hazards from lead in these media may be higher than usually assumed.

2. LEAD BIOAVAILABILITY AND BIOACCESSIBILITY STUDIES

2.1 IN VIVO STUDY

2.1.1 Study Design

The study design was patterned after the standardized study protocol for measuring relative bioavailability of lead (USEPA, 2004a) using the juvenile swine model. The basic design is presented in Table 2-1. As shown, the study investigated lead absorption from lead acetate (the reference material)

and one soil sample (the test material). Each material was administered to groups of five animals at three different dose levels for 15 days (a detailed schedule is presented in Appendix A, Table A-1). Additionally, the study included a non-treated group of three animals to serve as a control for determining background lead levels. All doses were administered orally. The study was performed as nearly as possible within the spirit and guidelines of Good Laboratory Practices (GLP: 40 CFR 792).

Table 2-1. In vivo study design.

Group	Number of Animals	Dose Material Administered	Lead Dose (µg/kg-day)	
			Target	Actual [a]
1	3	Control	0	0
2	5	Lead Acetate	25	25.3
3	5	Lead Acetate	75	76.3
4	4 [b]	Lead Acetate	225	226 7
5	5	Test Material	75	77.1
6	5	Test Material	225	230.13
7	5	Test Material	675	685.91

Notes [a] Calculated as the administered daily dose divided by the measured or extrapolated daily body weight, averaged over days 0-14 for each animal and each group

[b] One pig in group died, value shown is number of animals at completion of study (i.e., number included in data analysis).

Doses were administered in two equal portions given at 9.00 am and 3.00 p.m. each day. Doses were based on the mean weight of the animals in each group, and were adjusted every three days to account for weight gain.

2.1.2 Test Material

2.1.2.1 Sample Description

The test material for this study consisted of a soil sample designated "HER-2930" collected from the Herculaneum Lead Smelter test plot.

2.1.2.2 Sample Preparation

The soil sample was air-dried and sieved through a 250-micrometer (µm) sieve prior to test substance analysis and characterization. Only material that passed through the sieve (corresponding to particles smaller than about 250 µm) were used in the bioavailability study. The study was limited to this fine-grained soil fraction because it is believed that soil particles less than about 250 µm are most likely to adhere to the hands and be ingested by hand-to-mouth contact, especially in young children.

2.1.2.3 Lead Concentration

The concentration of lead in the soil test material was measured in triplicate by flame atomic absorption. The resulting mean lead value was 2021 µg/g.

2.1.3 Experimental Animals

Juvenile swine were selected for use in this study because they are considered to be a good physiological model for gastrointestinal absorption in children (Weis and LaVelle, 1991; Casteel et al., 1996). The animals were intact males of the Pig Improvement Corporation (PIC) genetically defined Line 26, and were purchased from Chinn Farms, Clarence, Missouri.

The number of animals purchased for the study was several more than required by the protocol. These animals were purchased at an age of about 5-6 weeks (weaning occurs at age 3 weeks) and housed in individual lead-free stainless steel cages. The animals were then held under quarantine for one week to observe their health before beginning exposure to test materials. Each animal was examined by a certified veterinary clinician (swine specialist) and any animals that appeared to be in poor health during this quarantine period were excluded from the study. To minimize weight variations among animals and groups, extra animals most different in body weight (either heavier or lighter) four days prior to exposure (day -4) were also excluded from the study. The remaining animals were assigned to dose groups at random (group assignments are presented in Appendix A, Table A-2).

When exposure began (day zero), the animals were about 6-7 weeks old and weighed an average of about 11.1 kg. The animals were weighed every three days during the course of the study. On average, animals gained about 0.45 kg/day and the rate of weight gain was comparable in all dosing groups, ranging from 0.38 to 0.51 kg/day. These body weight data are summarized in Figure 2-1 and are also presented in Appendix A, Table A-3.

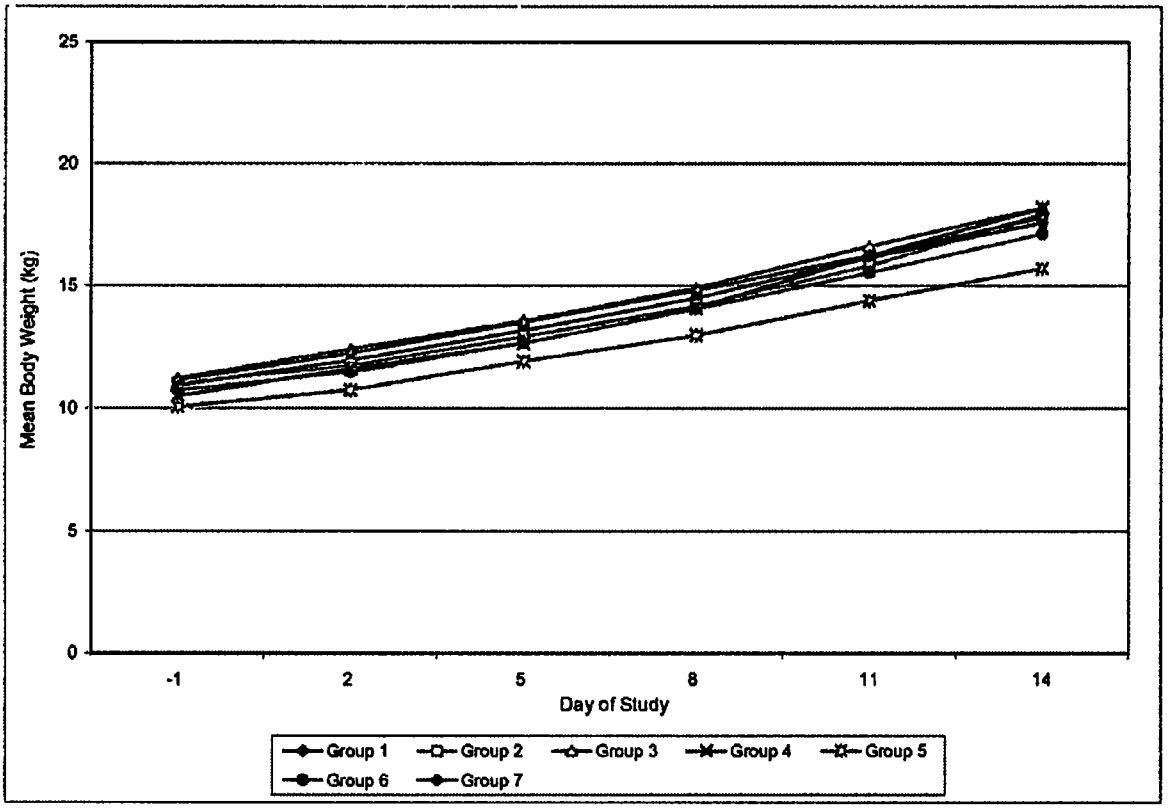


Figure 2-1. Body weight gain.

All animals were examined daily by an attending veterinarian while on study. Most animals (N = 21) exhibited no problems throughout the study. Several animals (N = 12) were treated for illness (e.g., fever, inappetance, diarrhea) with Naxcel (see Appendix A, Table A-4). In addition, one animal died during the course of the study (see Appendix A, Table A-4); data from this animal was excluded from all data analyses (Casteel et al., 2006).

2.1.4 Diet

Animals were weaned onto standard pig chow (purchased from MFA Inc., Columbia, Missouri) by the supplier. In order to minimize lead exposure from the diet, the animals were gradually transitioned from the MFA feed to a special low-lead feed (guaranteed less than 0.2 ppm lead, purchased from Zeigler Brothers, Inc., Gardners, Pennsylvania), and this feed was maintained for the duration of the study. The feed was nutritionally complete and met all requirements of the National Institutes of Health–National Research Council. The typical nutritional components and chemical analysis of the feed are presented in Table 2-2. Each day every animal was given an amount of feed equal to 5% of the mean body weight of all animals on study through day 2; beginning on day 3, the feed portion was changed to 4.5% of the mean body weight of all animals on study, as the animals had not been consuming all their feed. Feed amounts were adjusted every three days, when pigs were weighed. Feed was administered in two equal portions at 11:00 AM and 5:00 PM daily. Analysis of random low-lead feed samples indicated that the lead level did not exceed 0.05 µg/g.

Table 2-2. Typical feed compostion.

Nutrient Name	Amount
Protein	20.1021%
Arginine	1 2070%
Lysine	1.4690%
Methionine	0 8370%
Met+Cys	0 5876%
Tryptophan	0 2770%
Histidine	0 5580%
Leucine	1.8160%
Isoleucine	1 1310%
Phenylalanine	1 1050%
Phe+Tyr	2 0500%
Threonine	0 8200%
Valine	1 1910%
Fat	4 4440%
Saturated Fat	0 5590%
Unsaturated Fat	3 7410%
Linoleic 18.2.6	1.9350%
Linoleic 18 3 3	0 0430%
Crude Fiber	3 8035%
Ash	4 3347%
Calcium	0 8675%
Phos Total	0 7736%
Available Phosphorous	0 7005%
Sodium	0 2448%
Potassium	0 3733%

Nutrient Name	Amount
Chlorine	0 1911%
Magnesium	0 0533%
Sulfur	0 0339%
Manganese	20.4719 ppm
Zinc	118 0608 ppm
Iron	135 3710 ppm
Copper	8 1062 ppm
Cobalt	0.0110 ppm
Iodine	0 2075 ppm
Selenium	0.3196 ppm
Nitrogen Free Extract	60 2340%
Vitamin A	5 1892 kIU/kg
Vitamin D3	0 6486 kIU/kg
Vitamin E	87 2080 IU/kg
Vitamin K	0 9089 ppm
Thiamine	9 1681 ppm
Riboflavin	10.2290 ppm
Niacin	30 1147 ppm
Pantothenic Acid	19 1250 ppm
Choline	1019 8600 ppm
Pyridoxine	8 2302 ppm
Folacin	2 0476 ppm
Biotin	0.2038 ppm
Vitamin B12	23 4416 ppm

Feed obtained from and nutritional values provided by Zeigler Bros , Inc

Drinking water was provided *ad libitum* via self-activated watering nozzles within each cage. Analysis of samples from randomly selected drinking water nozzles indicated the lead concentration did not exceed 3 µg/L.

2.1.5 Dosing

The protocol for exposing animals to lead is shown in Table 2-1. The dose levels for lead acetate were based on experience from previous swine investigations that showed that lead doses of 25-225 µg/kg-day resulted in clear and measurable increases in lead levels in all endpoints measured (blood, liver, kidney, and bone). The actual administered doses were calculated based on the lead content of the material administered and the

measured group mean body weights. Specifically, doses of lead for the three days following each weighing were based on the group mean body weight adjusted by the addition of 1 kg to account for the expected weight gain over the time interval. After completion of the study, body weights were estimated by interpolation for those days when measurements were not collected and the actual administered doses were calculated for each day and then averaged across all days. The actual mean doses for each dosing group are included in Table 2-1; the actual lead doses administered to each pig are presented in Appendix A, Table A-3.

Animals were exposed to lead acetate or the test material for 15 days, with the dose for each day being administered in two equal portions beginning at 9:00 AM and 3:00 PM (two hours before feeding), with two minute intervals allowed for individual pig dosing. Dose material was placed in the center of a small portion (about 5 grams) of moistened feed (this is referred to as a "doughball"), and this was administered to the animals by hand[1]. If uneaten portions of doughballs were discovered, these were retrieved and offered again for consumption. Occasionally, some animals did not consume their entire dose. In these instances, the missed doses were estimated and recorded and the time-weighted average dose calculation for each animal was adjusted downward accordingly (see Appendix A, Table A-3).

2.1.6 Collection of Biological Samples

Samples of blood were collected from each animal on the first day of exposure (day 0) and on days 1, 2, 3, 5, 7, 9, 12, and 15 following the start of exposure. All blood samples were collected by vena-puncture of the anterior vena cava, and samples were immediately placed in purple-top Vacutainer® tubes containing EDTA (ethylenediaminetetra-acetic acid) as anticoagulant. Although EDTA is a chelator of metals, the nitric acid digest used in the analysis destroys the organic constituents in the blood, thereby freeing all lead for analysis. Thus, the presence of EDTA in the sampling tubes will not impact the analytical results for lead. Blood samples were collected each sampling day beginning at 8:00 AM, approximately one hour before the first of the two daily exposures to lead on the sampling day and 17 hours after the last lead exposure the previous day. This blood collection time was selected because the rate of change in blood lead resulting from the preceding exposures is expected to be relatively small after this interval (LaVelle et al., 1991; Weis et al., 1993), so the exact timing of sample collection relative to the last dosing is not likely to be critical.

Following collection of the final blood sample on day 15, all animals were humanely euthanized and samples of liver, kidney, and bone (the right femur, defleshed) were removed and stored at -80°C in lead-free plastic bags for lead analysis.

Samples of all biological samples collected were archived in order to allow for reanalysis and verification of lead levels, if needed. All animals were also subjected to detailed examination at necropsy by a certified veterinary pathologist in order to assess overall animal health.

2.1.7 Preparation of Biological Samples for Analysis

2.1.7.1 Blood

One mL of whole blood was removed from the purple-top Vacutainer® tube and added to 9.0 mL of "matrix modifier," a solution recommended by the Centers for Disease Control and Prevention (CDCP) for analysis of blood samples for lead. The composition of matrix modifier is 0.2% (v/v) ultrapure nitric acid, 0.5% (v/v) Triton X-100, and 0.2% (w/v) dibasic ammonium phosphate in deionized distilled water.

[1] Doughballs were kept as small as possible. About one-third of the way through the study, the dose for Group 7 (high dose soil) was split between two doughballs.

2.1.7.2 Liver and Kidney

One gram of soft tissue (liver or kidney) was placed in a lead-free screw-cap Teflon container with 2 mL of concentrated (70%) nitric acid and heated in an oven to 90°C overnight. After cooling, the digestate was transferred to a clean lead-free 10 mL volumetric flask and diluted to volume with deionized distilled water.

2.1.7.3 Bone

The right femur of each animal was defleshed, broken, and dried at 100°C overnight. The dried bones were then placed in a muffle furnace and dry-ashed at 450°C for 48 hours. Following dry ashing, the bone was ground to a fine powder using a lead-free mortar and pestle, and 200 mg was removed and dissolved in 10.0 mL of 1:1 (v:v) concentrated nitric acid/water. After the powdered bone was dissolved and mixed, 1.0 mL of the acid solution was removed and diluted to 10.0 mL in deionized distilled water.

2.1.8 Lead Analysis

Samples of biological tissue (blood, liver, kidney, and bone) and other materials (e.g., food, water, reagents, solutions) were analyzed for lead by graphite furnace atomic absorption using a Perkin Elmer AAnalyst 800 high-performance atomic absorption spectrometer. Internal quality assurance samples are described in Section 2.3 of the MSE (main) report.

All analytical results were reported in units of µg Pb/L (ng/mL) of prepared sample. The quantitation limit was defined as three-times the standard deviation of a set of seven replicates of a low-lead sample (typically about 2-5 µg/L). The standard deviation was usually about 0.3 µg/L, so the quantitation limit was usually about 0.9-1.0 µg/L. For prepared blood samples (diluted 1/10), this corresponds to a quantitation limit of 10 µg/L (1 µg/dL). For soft tissues (liver and kidney, diluted 1/10), this corresponds to a quantitation limit of 10 µg/kg (ng/g) wet weight, and for bone (diluted 1/500) the corresponding quantitation limit is 0.5 µg/g (ng/mg) ashed weight. All responses below the quantitation limit were evaluated at one-half the quantitation limit.

Lead analytical results for study samples are presented in Appendix A, Table A-5; the results for quality assurance samples are presented in Appendix A, Table A-6, and are summarized below (Casteel et al., 2006).

2.2 IN VITRO BIOACESSABILITY STUDY

In addition to the in vivo work using young swine, in vitro determinations were performed by Dr. John Drexler of the University of Colorado. In vitro methods have been developed for measuring the portion of Pb solubilized from soil materials under simulated gastrointestinal conditions (Ruby et al., 1996). These results, often referred to as the bioaccessible fraction (BAF), are thought to be an important determinant of bioavailability. Thus, BAF is not necessarily equal to RBA, but depends on the relation between results from a particular in vitro test system and an appropriate in vivo model/test animal (Ruby et al., 1999).

The in vitro tests simulate the gastrointestinal environment via sequential extraction of Pb (from soil, etc.) using strong acid and paraneutral aqueous solutions; these fluids mimic the pH conditions found in the stomach and small intestine, respectively. The extract is filtered (0.45 µm) and then analyzed for its Pb content. The mass of Pb found in the aqueous phase, divided by the Pb mass introduced in the test,

represents the sample-specific BAF. To date, for Pb-contaminated soils, the in vitro method has correlated well with the RBA values (USEPA, 2004a).

The in vitro bioaccessibility portion of the study used an EPA-approved method (extraction) and analysis methodologies, plus quality assurance/quality control guidance (EPA, 2005). Essentially, the extraction step uses 100 mL of pH 1.5 fluid (prepared using concentrated hydrochloric acid and containing 0.4 moles/liter glycine) and 1 gram of soil. The mixture is placed in a 125-mL high-density polyethylene bottle, sealed, and then agitated at 30 revolutions per minute for 1 hour at 37 °C on a modified TCLP extractor. Assuming maintenance of the above pH, the solution is passed through a 0.45-μm disk filter, and then the filtrate is stored at 4 °C until analyzed. The solution is then analyzed for Pb using ICP-AES (SW-846-6010B; USEPA, 2004b).

2.3 QUALITY ASSURANCE FOR THE IN VIVO STUDY

2.3.1 University of Missouri Activities

A number of quality assurance (QA) steps were taken during this project to evaluate the accuracy of the analytical procedures. These activities are discussed below.

2.3.1.1 Spike Recovery

Randomly selected samples were spiked with known amounts of lead (as lead acetate) and the recovery of the added lead was measured. Recovery for individual samples ranged from 83% to 118%, with an average of 99 ± 8.1% (N = 34).

2.3.1.2 Duplicate Analysis of Sample Digestate

Periodically during sample analysis, samples were randomly selected for duplicate analysis (i.e., the same prepared sample was analyzed twice). All duplicate results (N = 44) agreed within ±15% relative percent difference (RPD) (for analytical results greater than 10 μg/L) or ±1 μg/L (for analytical results less than or equal to 10 μg/L), as required by the analytical protocol.

2.3.1.3 Sample Preparation Replicates

A random selection of about 20% of all tissue samples generated during the study were prepared for laboratory analysis in duplicate (i.e., two separate subsamples of blood/tissue were prepared for analysis). The results for these replicate preparations are summarized in Figure 2-2. As seen, the analytical results for replicate pairs of blood samples (Panel A of Figure 2-2) tend to follow the line of equality, indicating that the replicate pairs are generally in good agreement. The absolute difference between replicate pairs of blood samples ranged from 0 to 3.0 μg/dL with an average of 0.65 μg/dL (N = 27). As seen, there was also good reproducibility between replicate samples for tissues (Panels B and C of Figure 2-2). The absolute difference between replicate pairs of liver and kidney samples ranged from 0 to 0.03 ng/g with an average of 0.01 ng/g (N = 6). The absolute difference between replicate pairs of femur samples ranged from 0.0 to 0.8 μg/g with an average of 0.33 μg/g (N = 3).

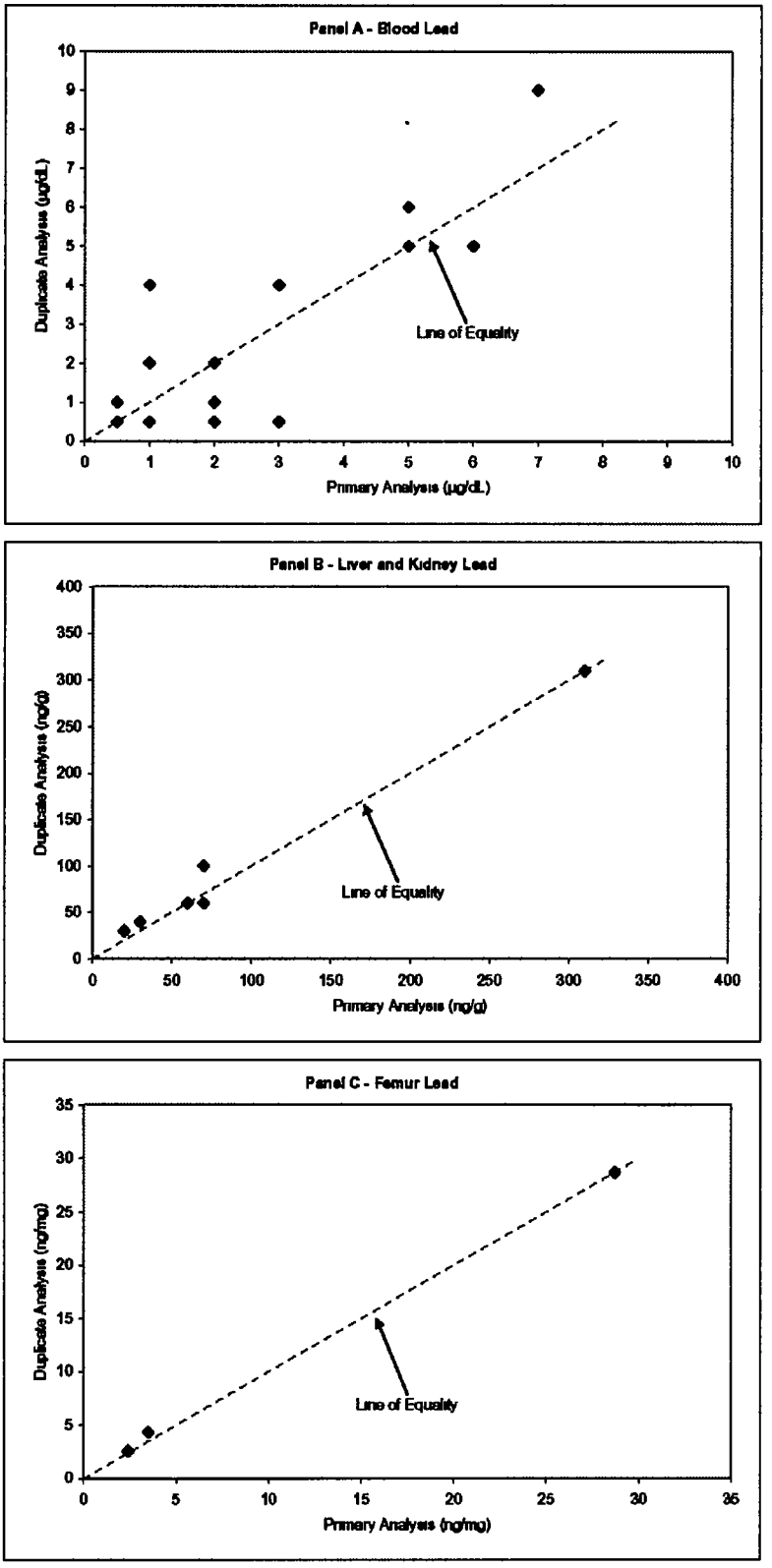


Figure 2-2. Sample preparation replicates.

2.3.1.4 Laboratory Control Standards

Laboratory control standards (samples of reference materials for which a certified concentration of lead has been established) were tested periodically during sample analysis. Results for the standards are summarized in Table 2-3.

Table 2-3. Summary of laboratory control standards for the in vivo study.

Standard	Target Value (Acceptable Range)	Mean	Range	SD	Mean % Recovery	N
ERA Quality Control Std 697, 1/5	17 5 (15.75 – 19.25)	18 2	16.3 – 19.2	0.9	104 2%	17
ERA Quality Control Std 697, 1/10	8.75 (7 9 – 9 6)	8.99	8.2 – 9.6	0.3	102.7%	43
DOLT-3 (dogfish liver)	0 319 (0 274 – 0 365)	0.255	0.24 – 0 27	0.021	79 9%	2
TORT-2 (lobster hepatopancreas)	0 35 (0 22 – 0.48)	0 26	0 24 – 0 27	0.019	72.9%	2
NIST SRM 1400 (bone ash)	9 07 (8 95 – 9.19)	9 09	–	–	100.2%	1
LUTS-1 (lobster hepatopancreas)	0 010 (0.008 – 0.012)	< DL (0.01)	–	–	–	1

As seen, recovery of lead from these standards was generally good and within the acceptable range.

2.3.1.5 Blood Lead Check Samples

The CDCP provides a variety of blood lead "check samples" for use in quality assurance programs for blood lead studies. Several CDCP check samples of different concentrations were analyzed periodically during blood sample analysis. The results are summarized in Figure 2-3. The results for all standards generally cluster around the line of equality, but tend to be slightly lower than expected; the reason for this is not known.

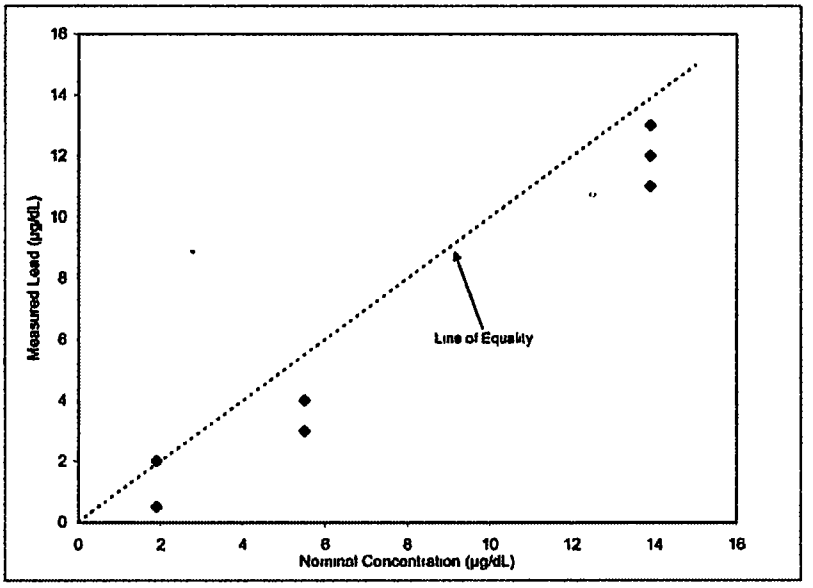


Figure 2-3. CDCP blood lead check samples.

2.3.1.6 Blanks

Samples of the sample preparation matrix for each endpoint (without added tissue) were routinely analyzed for lead to ensure the absence of lead contamination. These matrix blanks never yielded a measurable level of lead, with all values being reported as less than 1 μg/L (N = 60).

Based on the results of all of the quality assurance samples and steps described above, it is concluded that the analytical results are of sufficient quality for derivation of reliable estimates of lead absorption from test materials.

2.3.2 Technical Systems Audit of the VMDL Activities by MSE

2.3.2.1 Introduction

On June 14, 2005, a technical systems audit (TSA) of procedures for field and subsequent laboratory analytical activities for the *Investigation of Lead-Contaminated Soils and Lead Ore Concentrate Bioavailability Rates, Subtask 2- Determination of Lead Ore Concentrate Bioavailability Rates, Regional Applied Research (RARE) Project* was performed at the UM/VMDL in Columbia, Missouri. The audit was conducted by Ken Reick of MSE Technology Applications, Inc. (MSE). The purpose of the project is to determine the relative bioavailability of lead in weathered lead ore concentrate, using young swine as the test species.

The criterion upon which the TSA was based was the approved project-specific quality assurance project plan (QAPP), as well as universally recognized good field and laboratory practices.

2.3.2.2 Audit Procedures

The TSA commenced at 8:15 AM and concluded at 4:10 PM. The scope of the TSA included:

- personnel;
- equipment;
- documentation (logbooks and chain-of-custody forms);
- sampling procedures;
- analytical procedures; and
- procedural completeness.

There were no TSA findings or observations for any of the above areas. Findings are defined as: non-conformances at the project level that may have a significant adverse effect on quality. Observations are defined as: non-conformances at the project level that may not have a significant adverse effect on quality. Additional technical comments are defined as: items identified during the course of the audit that were not specified in the QAPP, but should be addressed to improve the operation of the project.

2.3.2.3 Audit Results

Personnel

The personnel present during the review were Ken Reick (MSE QA Staff), Dr. Stan W. Casteel, Margaret Dunsmore, Ashley Akeman, John Borzillo, and Dr. Genny Fent. Dr. Casteel is the UM/VMDL representative and is an internationally-recognized veterinary toxicologist. Ms. Dunsmore is the UM/VMDL QA Officer and analytical chemist with extensive experience in these fields. Dr. Fent is a

doctor of veterinary medicine, Ms. Akeman is working on her Animal Science degree, and Mr. Borzillo is an Animal Science graduate and will enter Veterinary School in the fall. All of these personnel were well versed in their project responsibilities.

There were no findings, observations, or technical comments for this portion of the TSA.

Equipment Description

The young swine used in the in vivo bioavailability studies are kept in separate stainless steel lead-free cages. The equipment used for obtaining blood samples consists of a syringe and Vacutainer tubes. The equipment used for analyzing the blood, soil, tissue, and bone samples is an AA Analyst – 800 Perkin Elmer THGA graphite furnace atomic abdsorption spectrophotometer.

Following the collection of blood samples (discussed in Section 2.1.6), dosing the swine commenced at 9:00AM. Each swine was dosed at two-minute intervals. At 11:00 AM, feeding commenced. This also was at two-minute intervals. Equipment used were scales and a feeding tray in front of each cage. There were no findings, observations or technical comments for this portion of the TSA.

Documentation

All sampling information was recorded in a logbook and backed up electronically. Sample labeling information was prerecorded on the Vacutainers.

A chain-of-custody for soil samples delivered to the UM/VMDL from Lincoln University was examined. All of the required information was on the chain-of-custody form.

There were no findings or observations for this portion of the TSA.

Sampling Procedures

The only sampling procedures that were observed during the TSA were obtaining blood samples. The pigs are picked up by their hind legs and placed on their back on a concave pillow underneath a plastic sheet. The person operating the syringe holds the pig's mouth shut as blood is being drawn. The Vacutainer tubes are refrigerated after collection.

The sampling procedures went smoothly and were carried out professionally. There were no findings and or observations in this portion of the TSA.

Laboratory Analytical Procedures

Although there were no analytical laboratory procedures being conducted on the day of the TSA, Ms. Dunsmore, Dr. Casteel and Dr. Fent explained the analytical procedures and provided documentation that is used, including applicable SOPs. Ms. Dunsmore also operated the Perkin Elmer AA and explained the various software programs that operate the instrument.

There were no findings or observations for this portion of the audit.

Procedural Completeness

During the TSA, which included reviews of the SOPs used by the staff, it was discovered that the procedures contained in the project QAPP, particularly the SOPs, are not entirely compatible with the

procedures being used at the UM/VMDL. It was apparent that thorough reviews of the various drafts of the QAPP were not adequately performed. This is a technical comment.

Recommended corrective actions resulting from the audit are summarized below:

- Review the QAPP for correctness as drafts become available and inform the person writing the QAPP of any inconsistencies or deficiencies.
- UM/VMDL personnel should make available to MSE QA personnel all the pertinent SOPs being used for this study so that the QAPP can be updated.

2.4 QUALITY ASSURANCE FOR THE IN VITRO STUDY

2.4.1 Extraction Fluid Analysis

Filtered samples of extraction fluid were stored in a refrigerator at 4 °C until they were analyzed (within 1 week of extraction). Filtered samples were analyzed for lead by ICP-AES or ICP-MS (EPA Method 6010 or 6020). Method detection limits (MDS) in extraction fluid were calculated to be 19 and 0.1 µg/L for Methods 6010 and 6020, respectively (USEPA, 2004b).

2.4.2 Quality Control/Quality Assurance

Quality assurance for the extraction procedure consisted of the following quality control samples.

- Reagent Blank – extraction fluid analyzed once per batch.
- Bottle Blank – extraction fluid only (no test soil) run through the complete procedure at a frequency of 1 in 20 samples.
- Blank Spike – extraction fluid spiked at 10 mg/L lead, and run through the complete procedure at a frequency of 1 in 20 samples.
- Matrix Spike – a subsample of each material used for duplicate analyses was used as a matrix spike. The spike was prepared at 10 mg/L and run through the extraction procedure at a frequency of 1 in 10 samples.
- Duplicate Sample – duplicate sample extractions were performed on 1 in 10 samples.
- Control Soil – National Institute of Standards and Testing (NIST) Standard Reference Material (SRM) 2711 (Montana Soil) was used as a control soil. The SRM was analyzed in triplicate.

Control limits for these quality control samples are shown in Table 2-4.

Table 2-4. Summary of quality control limits for the in vitro study.

Analysis	Frequency	Control Limits
Reagent blank	once per batch	< 25 µg/L lead
Bottle blank	5%	< 50 µg/L lead
Blank spike (10 mg/L)	5%	85%-115% recovery
Matrix spike (10 mg/L)	10%	75%-125% recovery
Duplicate sample	10%	± 20% RPD [a]
Control soil (NIST 2711)	5%	± 10% RPD [a]

Note [a] RPD = relative percent difference

To evaluate the precision of the in vitro bioaccessibility extraction protocol, approximately 67 replicate analyses of both NIST SRM 2710 and 2711 have been conducted over a period of several months. Both standards yield highly reproducible results, with a mean coefficient of variation of about 6%.

3. DATA ANALYSIS

3.1 OVERVIEW

The basic approach for measuring lead absorption *in vivo* is to administer an oral dose of lead to test animals and measure the increase in lead level in one or more body compartments (e.g., blood, soft tissue, bone). In order to calculate the RBA value of a test material, the increase in lead in a body compartment is measured both for that test material and a reference material (lead acetate). Because equal absorbed doses of lead (as Pb^{+2}) will produce equal responses (i.e., equal increases in concentration in tissues) regardless of the source or nature of the ingested lead, the RBA of a test material is calculated as the ratio of doses (test material and reference material) that produce equal increases in lead concentration in the body compartment. Thus, the basic data reduction task required to calculate an RBA for a test material is to fit mathematical equations to the dose-response data for both the test material and the reference material, and then solve the equations to find the ratio of doses that would be expected to yield equal responses.

Some biological responses to lead exposure may be non-linear functions of dose (i.e., tending to flatten out or plateau as dose increases). The cause of this non-linearity is uncertain but might be due either to non-linear absorption kinetics and/or to non-linear biological response per unit dose absorbed. However, the principal advantage of the approach described above is that it is not necessary to understand the basis for a non-linear dose response curve (non-linear absorption and/or non-linear biological response) in order to derive valid RBA estimates; in addition, this approach is general and yields reliable results for both non-linear and linear responses.

A detailed description of the curve-fitting methods and rationale, along with the methods used to quantify uncertainty in the RBA estimates for the test material, are presented in USEPA (2004a) and are summarized below.

3.2 MEASUREMENT ENDPOINTS

Four independent measurement endpoints were evaluated based on the concentration of lead observed in blood, liver, kidney, and bone (femur). For liver, kidney, and bone, the measurement endpoint was simply the concentration in the tissue at the time of sacrifice (day 15). The measurement endpoint used to quantify the blood lead response was the area under the curve (AUC) for blood lead vs. time (days 0-15). AUC was selected because it is the standard pharmacokinetic index of chemical uptake into the blood compartment, and is relatively insensitive to small variations in blood lead level by day. The AUC was calculated using the trapezoidal rule to estimate the AUC between each time point that a blood lead value was measured (days 0, 1, 2, 3, 5, 7, 9, 12, and 15):

$$AUC(d_i \text{ to } d_j) = 0.5 \cdot (r_i + r_j) \cdot (d_j - d_i)$$

where:

d = day number
r = response (blood lead value) on day i (r_i) or day j (r_j)

The areas were then summed across all time intervals in the study to yield the final AUC for each animal.

Occasionally blood lead values are obtained that are clearly different than expected. Blood lead values that were more than a factor of 1.5 above or below the group mean for any given day were flagged as potential outliers and are shaded in Appendix A, Table A-7. Each data point identified in this way was reviewed and professional judgment was used to decide if the value should be retained or excluded. In order to avoid inappropriate biases, blood lead outlier designations are restricted to values that are clearly aberrant from a time-course and/or dose-response perspective. In this study, no values were judged to be a clear outlier; all blood lead data were included in the calculation of AUC.

3.3 DOSE-RESPONSE MODELS

3.3.1 Basic Equations

It has been shown previously (USEPA, 2004a) that nearly all blood lead AUC data sets can be well-fit using an exponential equation and most tissue (liver, kidney, and bone) lead data can be well-fit using a linear equation, as follow:

Linear (liver, kidney, bone): Response = a + b · Dose
Exponential (blood lead AUC): Response = a + b · [1 - exp(-c · Dose)]

3.3.2 Simultaneous Regression

Because the data to be analyzed consist of three dose-response curves for each endpoint (the reference material and two test materials) and there is no difference between the curves when the dose is zero, all three curves for a given endpoint must have the same intercept. This requirement is achieved by combining the two dose response equations into one and solving for the parameters simultaneously, resulting in the following equations:

Linear: $y = a + b_r \cdot x_r + b_t \cdot x_t$

Exponential: $y = a + b \cdot [\,(1-\exp(-c_r \cdot x_r)) + (1-\exp(-c_t \cdot x_t))\,]$

where:

y = response
x = dose
a, b, c = empirical coefficients for the reference material (r) and test material (t).

All linear model fitting was performed in Microsoft® Office Excel using matrix functions. Exponential model fitting was performed using JMP® version 3.2.2, a commercial software package developed by SAS®.

3.3.3 Weighted Regression

Regression analysis based on ordinary least squares assumes that the variance of the responses is independent of the dose and/or the response (Draper and Smith, 1998). It has previously been shown that this assumption is generally not satisfied in swine-based RBA studies, where there is a tendency toward increasing variance in response as a function of increasing dose (heteroscedasticity) (USEPA, 2004a). To deal with heteroscedasticity, the data are analyzed using weighted least squares regression. In this

approach, each observation in a group of animals is assigned a weight that is inversely proportional to the variance of the response in that group:

$$w_i = (\sigma^2_i)^{-1}$$

where:

w_i = weight assigned to all data points in dose group i
σ^2_i = variance of responses of animals in dose group i

(Draper and Smith, 1998).

As discussed in USEPA (2004a), there are several alternative strategies for assigning weights. The preferred method identified by USEPA (2004a) and the method used in this study estimates the value of σ^2_i using an "external" variance model based on an analysis of the relationship between variance and mean response using data consolidated from ten different swine-based lead RBA studies. Log-variance increases as an approximately linear function of log-mean response for all four endpoints:

$$\ln(s_i^2) = k1 + k2 \cdot \ln(\bar{y}_i)$$

where:

s_i^2 = observed variance of responses of animals in dose group i
$\bar{y}_i$ = mean observed response of animals in dose group i

Values of k1 and k2 were derived for each endpoint using ordinary least squares minimization, and the resulting values are shown below:

Endpoint	k1	k2
Blood AUC	–1.3226	1.5516
Liver	–2.6015	2.0999
Kidney	–1.8499	1.9557
Femur	–1.9713	1.6560

3.3.4 Goodness-of-Fit

The goodness-of-fit of each dose-response model was assessed using the F test statistic and the adjusted coefficient of multiple determination (Adj R^2) as described by Draper and Smith (1998). A fit is considered acceptable if the p-value is less than 0.05.

3.3.5 Assessment of Outliers

In biological assays, it is not uncommon to note the occurrence of individual measured responses that appear atypical compared to the responses from other animals in the same dose group. In this study, endpoint responses that yielded standardized weighted residuals greater than 3.5 or less than -3.5 were considered to be potential outliers (Canavos, 1984). When such data points were encountered in a data set, the RBA was calculated both with and without the potential outlier(s) excluded, and the result with the outlier(s) excluded was used as the preferred estimate.

3.4 CALCULATION OF RBA ESTIMATES

3.4.1 Endpoint-specific RBA Estimates

Lead RBA values were estimated using the basic statistical techniques recommended by Finney (1978). Each endpoint-specific RBA value was calculated as the ratio of a model coefficient for the reference material data set and for the test material data set:

Linear endpoints: $RBA_t = b_t / b_r$
Exponential endpoint: $RBA_t = c_t / c_r$

The uncertainly range about the RBA ratio was calculated using Fieller's Theorem as described by Finney (1978).

3.4.2 RBA Point Estimate

Because there are four independent estimates of RBA (one from each measurement endpoint) for a given test material, the final RBA estimate for a test material involves combining the four endpoint-specific RBA values into a single value (point estimate) and estimating the uncertainty around that point estimate. As described in USEPA (2004a), analysis of data from multiple studies suggests that the four endpoint-specific RBA values are all approximately equally reliable (as reflected in the average coefficient of variation in RBA values derived from each endpoint). Therefore, the RBA point estimate for the test material was calculated as the simple mean of all four endpoint-specific RBA values.

The uncertainty bounds around this point estimate were estimated using Monte Carlo simulation. Values for RBA were drawn from the uncertainty distributions for each endpoint with equal frequency. Each endpoint-specific uncertainty distribution was assumed to be normal, with the mean equal to the best estimate of RBA and the standard deviation estimated from Fieller's Theorem (Finney, 1978). The uncertainty in the point estimate was characterized as the range from the 5^{th} to the 95^{th} percentile of the mean across endpoints.

4. RESULTS

4.1 CLINICAL SIGNS

The doses of lead administered in this study are below a level that is expected to cause toxicological responses in swine, and no clinical signs of lead-induced toxicity were noted in any of the animals used in the study.

4.2 BLOOD LEAD VS. TIME

Blood lead data for individual animals are presented in Appendix A, Table A-7 and Figure A-1. Group mean blood lead values as a function of time are shown in Figure 4-1. As seen, blood lead values began at or below quantitation limits (about 1 μg/dL) in all groups, and remained at or below quantitation limits in control animals (Group 1). In animals given repeated oral doses of lead acetate (Groups 2-4) or test soil (Groups 5-7), blood levels began to rise within 1-2 days, and tended to plateau by the end of the study (day 15).

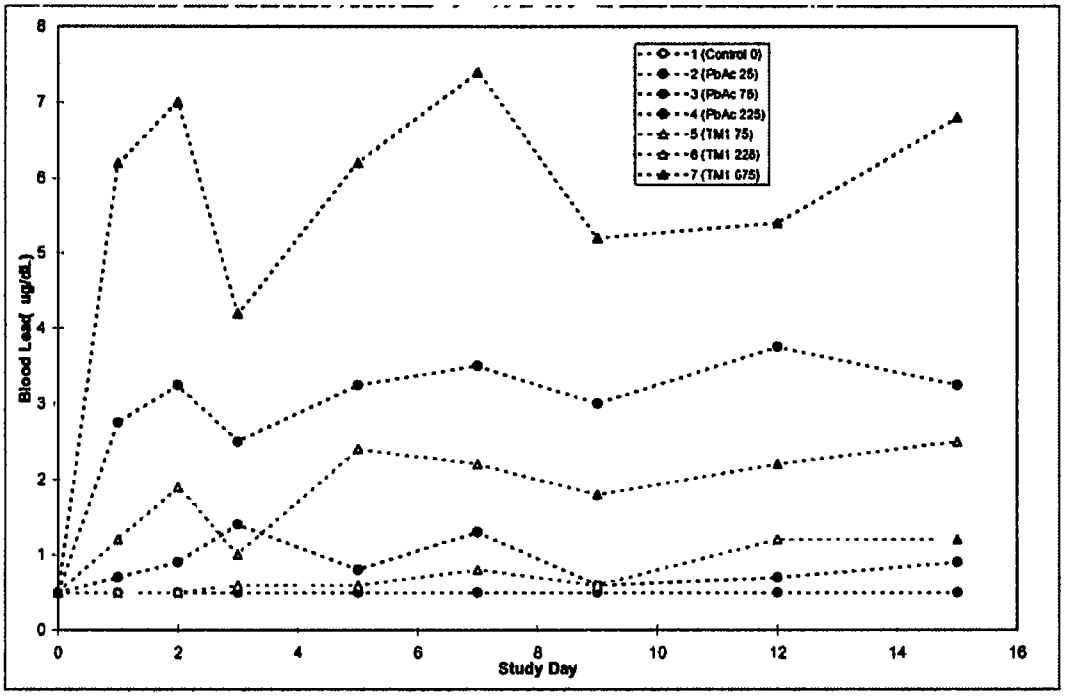


Figure 4-1. Group mean blood lead by day.

4.3 DOSE-RESPONSE PATTERNS

4.3.1 Variance

As discussed in Section 3.3, the dose-response data are analyzed using weighted least squares regression and the weights are assigned using an "external" variance model (USEPA, 2004). As shown in Figure 4-2, the variance of the data from this study is generally quite similar to that of the data used to generate the variance model for all four measurement endpoints.

4.3.2 Blood Lead AUC

As discussed in Section 3.2, the measurement endpoint used to quantify the blood lead response was the area under the curve (AUC) for blood lead vs. time (days 0-15). The AUC determinations are presented in Appendix A, Table A-8.

The blood lead AUC dose-response data were initially modeled using an exponential equation (see Section 3.3); however, a solution could not be obtained with this model. Although most blood lead AUC data sets can be well-fit using the exponential model, occasionally blood lead AUC data sets do not yield a solution or yield unstable solutions for the exponential model, as is the case here. As discussed in USEPA (2004a), the difficulty in modeling such data sets appears to be due to the fact that the data have relatively less curvature than most blood lead AUC data sets. Because of this lack of curvature, it is not possible to estimate the exponential plateau value (b) with confidence, which in turns makes it difficult to estimate the other parameters of the exponential model. In such cases, there are several alternative evaluation methods, including a) using the model fits from a different nonlinear model (e.g., power, Michaelis-Menton), b) using the fit for the linear model, and c) fitting the data to the exponential model using a defined value for the plateau based on results from other data sets. In USEPA (2004a), it was

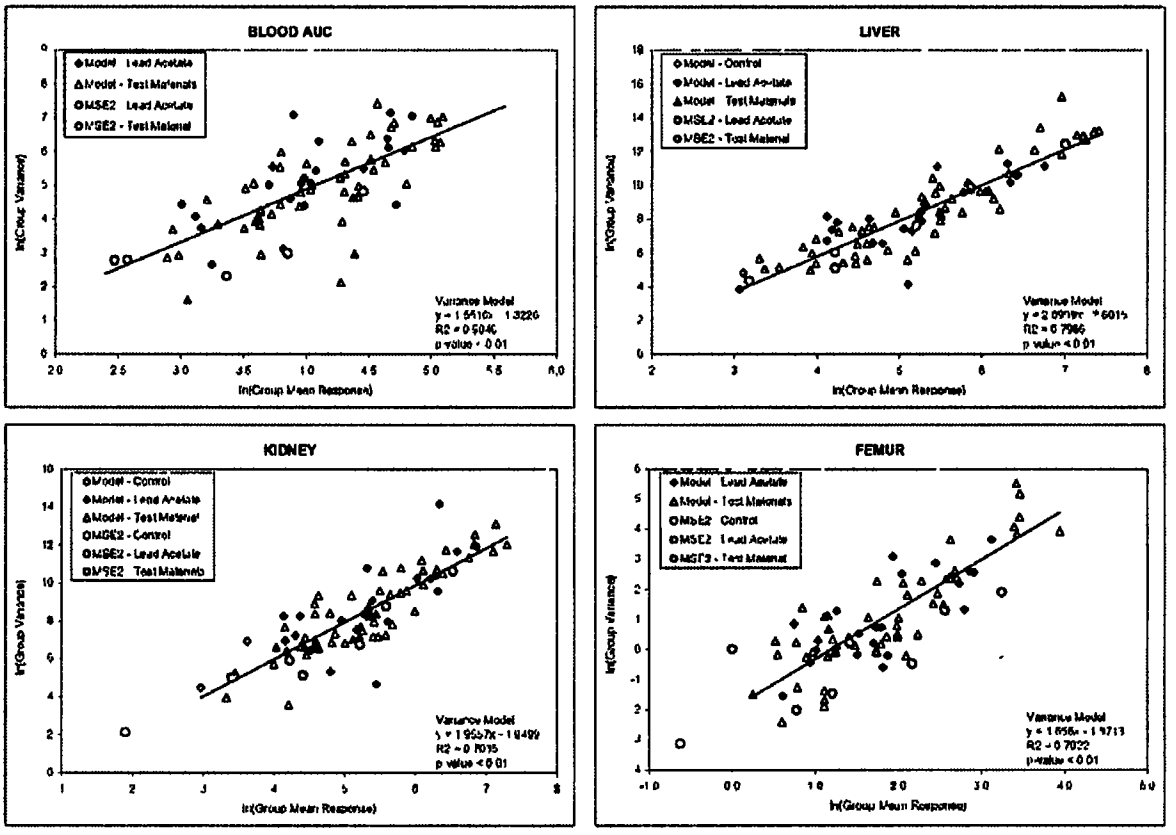


Figure 4-2. Variance models.

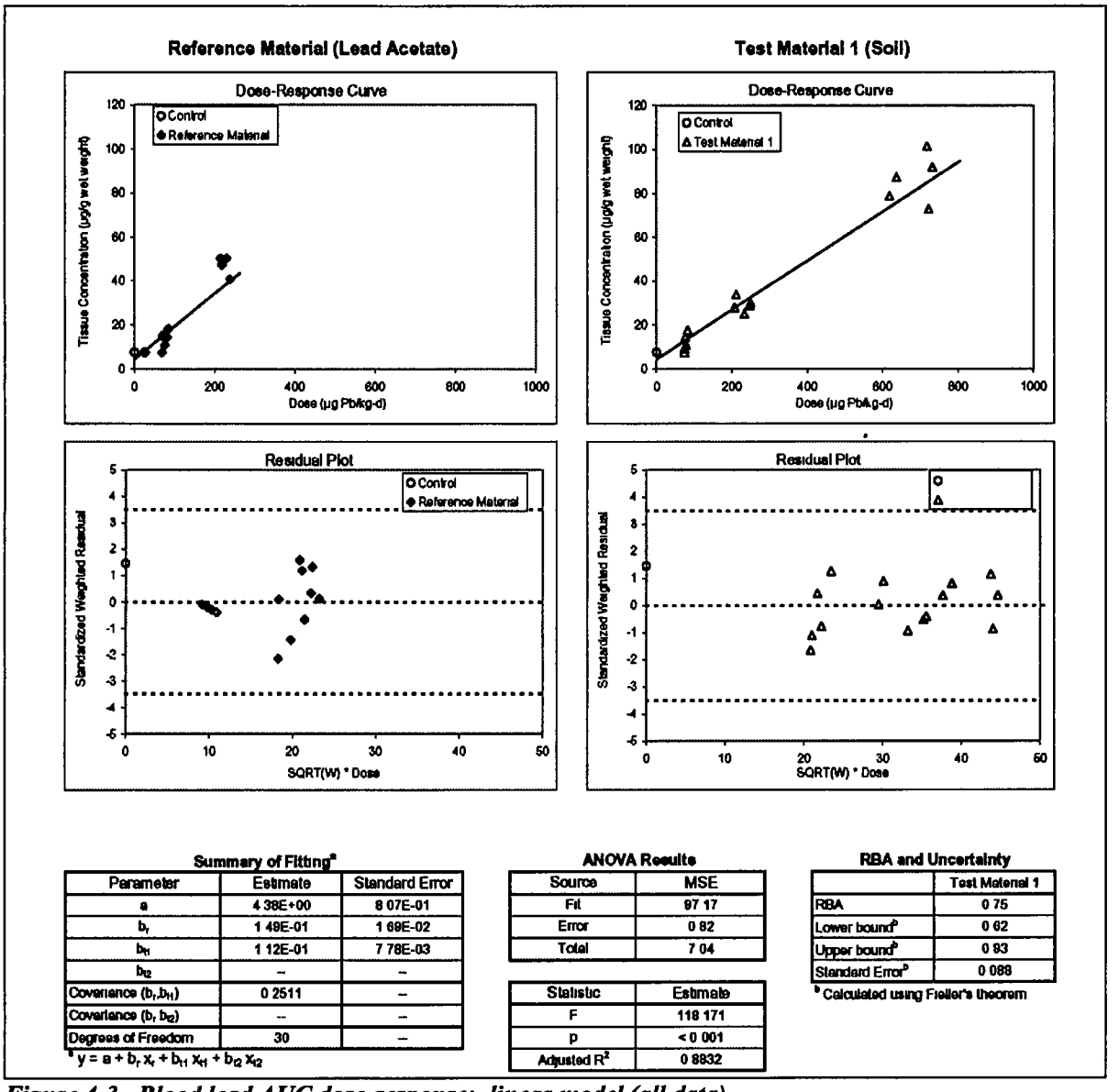
determined that the results (i.e., the RBA values based on the blood lead AUC endpoint) were generally similar for all three of these approaches and it was concluded that the results from the linear fit were an appropriate alternative to the exponential model in these cases. Therefore, the linear model was used for the blood lead AUC dose-response data in this study. The results of this fitting are shown in Figure 4-3.

4.3.3 Tissue Lead

The dose-response data for lead in liver, kidney, and bone (measured at sacrifice on day 15) were modeled using a linear equation (see Section 3.3). The results of these fittings are shown in Figures 4-4 (liver), 4-5 (kidney), and 4-6 (femur).

4.4 CALCULATED RBA VALUES

Relative bioavailability values for the test soil were calculated for each measurement endpoint (blood lead AUC, liver, kidney, and bone) using the method described in Section 3.4; the suggested point estimate is calculated as the simple mean of the four endpoint-specific estimates. The results are shown in Table 4-1.



Summary of Fitting[a]

Parameter	Estimate	Standard Error
a	4.38E+00	8.07E-01
b_r	1.49E-01	1.69E-02
b_{t1}	1.12E-01	7.78E-03
b_{t2}	--	--
Covariance (b_r,b_{t1})	0.2511	--
Covariance (b_r b_{t2})	--	--
Degrees of Freedom	30	--

[a] $y = a + b_r x_r + b_{t1} x_{t1} + b_{t2} x_{t2}$

ANOVA Results

Source	MSE
Fit	97.17
Error	0.82
Total	7.04

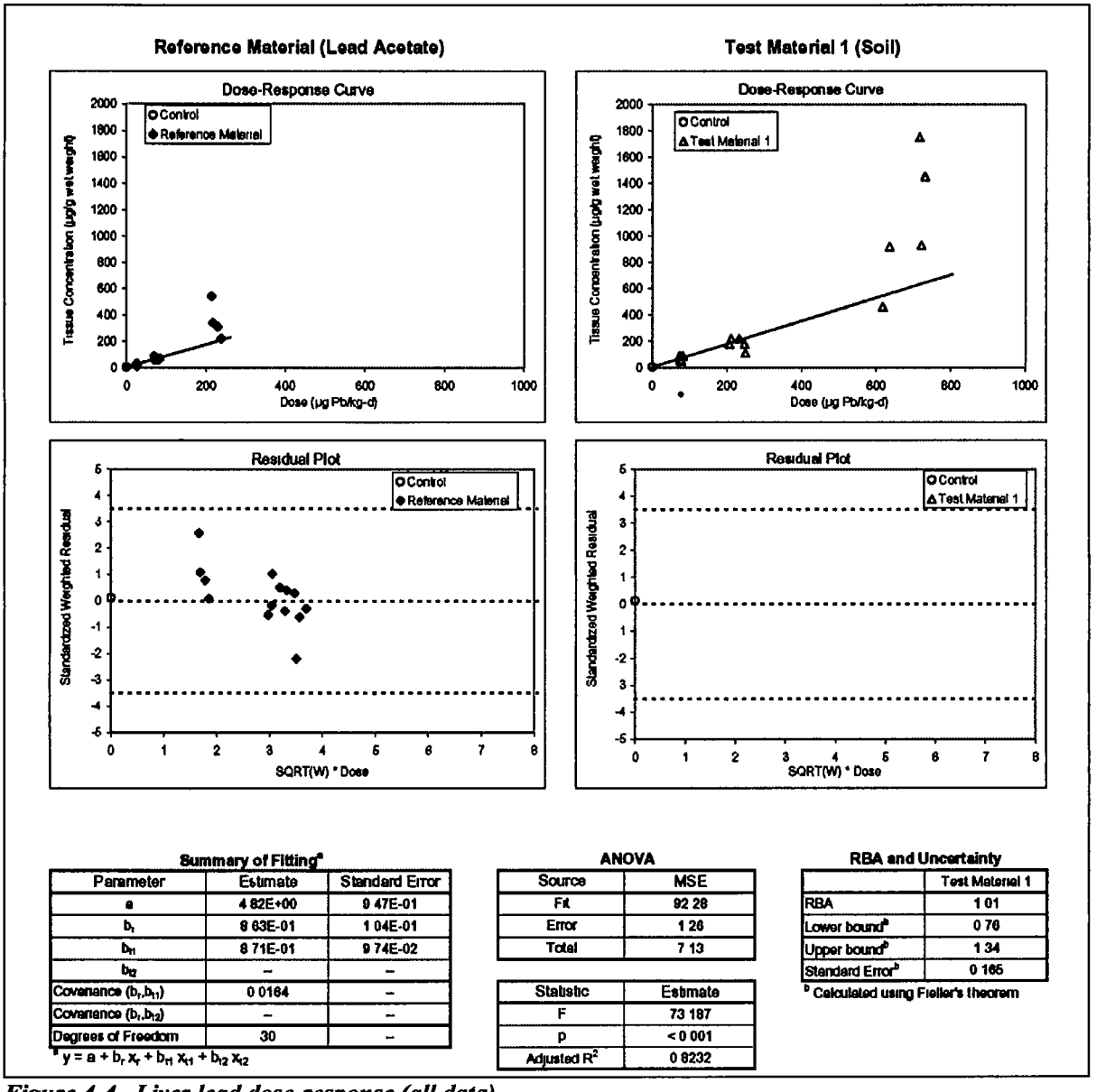
Statistic	Estimate
F	118.171
p	< 0.001
Adjusted R^2	0.8832

RBA and Uncertainty

	Test Material 1
RBA	0.75
Lower bound[b]	0.62
Upper bound[b]	0.93
Standard Error[b]	0.089

[b] Calculated using Fieller's theorem

Figure 4-3. Blood lead AUC dose-response: linear model (all data).



Summary of Fitting[a]

Parameter	Estimate	Standard Error
a	4 82E+00	9 47E-01
b_r	9 63E-01	1 04E-01
b_{t1}	8 71E-01	9 74E-02
b_{t2}	--	--
Covariance (b_r,b_{t1})	0 0164	--
Covariance (b_r,b_{t2})	--	--
Degrees of Freedom	30	--

[a] $y = a + b_r x_r + b_{t1} x_{t1} + b_{t2} x_{t2}$

ANOVA

Source	MSE
Fit	92 28
Error	1 26
Total	7 13

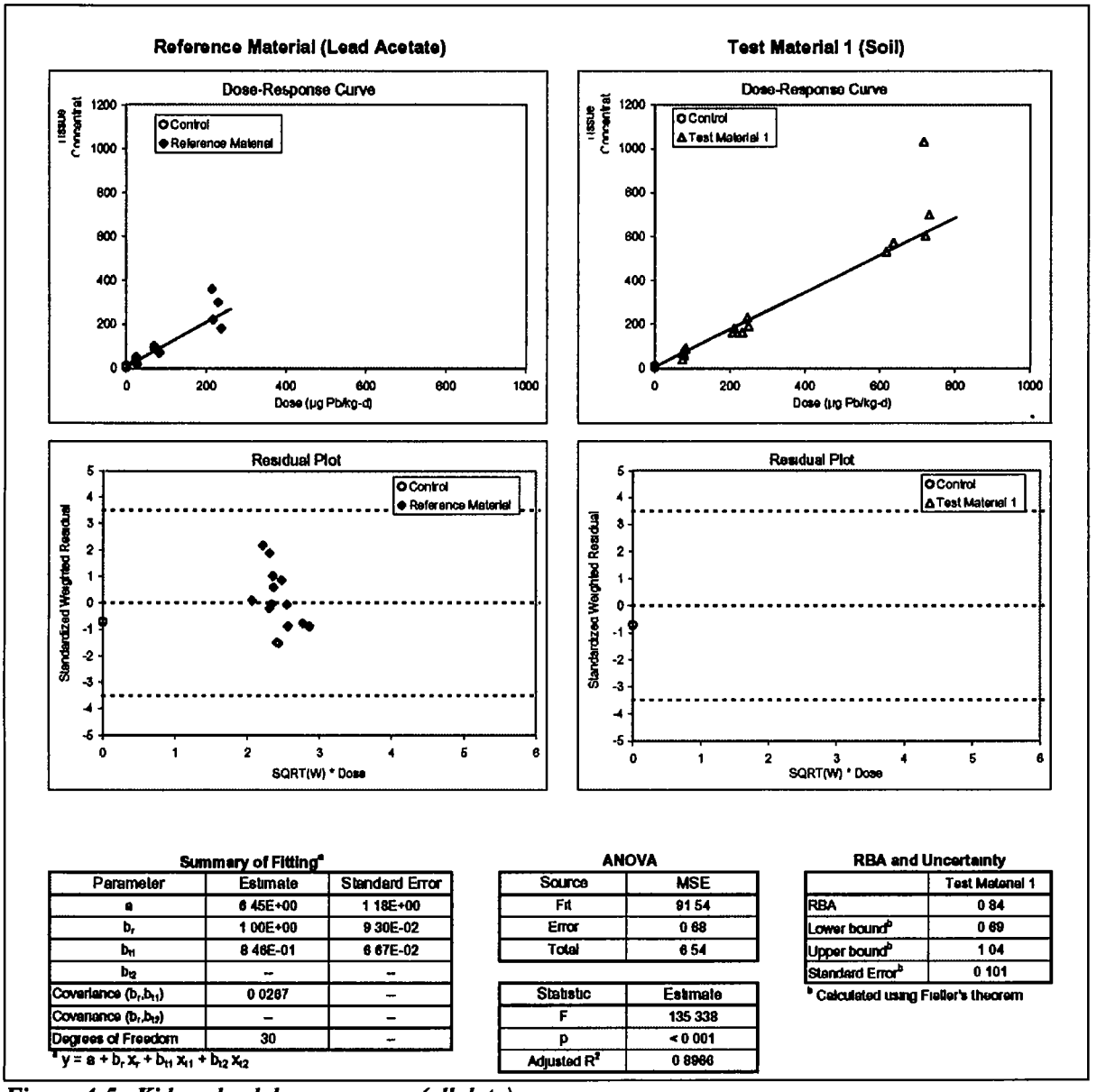
Statistic	Estimate
F	73 187
p	< 0 001
Adjusted R^2	0 8232

RBA and Uncertainty

	Test Material 1
RBA	1 01
Lower bound[b]	0 76
Upper bound[b]	1 34
Standard Error[b]	0 165

[b] Calculated using Fieller's theorem

Figure 4-4. Liver lead dose-response (all data).



Summary of Fitting[a]

Parameter	Estimate	Standard Error
a	6 45E+00	1 18E+00
b_r	1 00E+00	9 30E-02
b_{t1}	8 46E-01	6 67E-02
b_{t2}	--	--
Covariance (b_r,b_{t1})	0 0267	--
Covariance (b_r,b_{t2})	--	--
Degrees of Freedom	30	--

[a] $y = a + b_r x_r + b_{t1} x_{t1} + b_{t2} x_{t2}$

ANOVA

Source	MSE
Fit	91 54
Error	0 68
Total	6 54

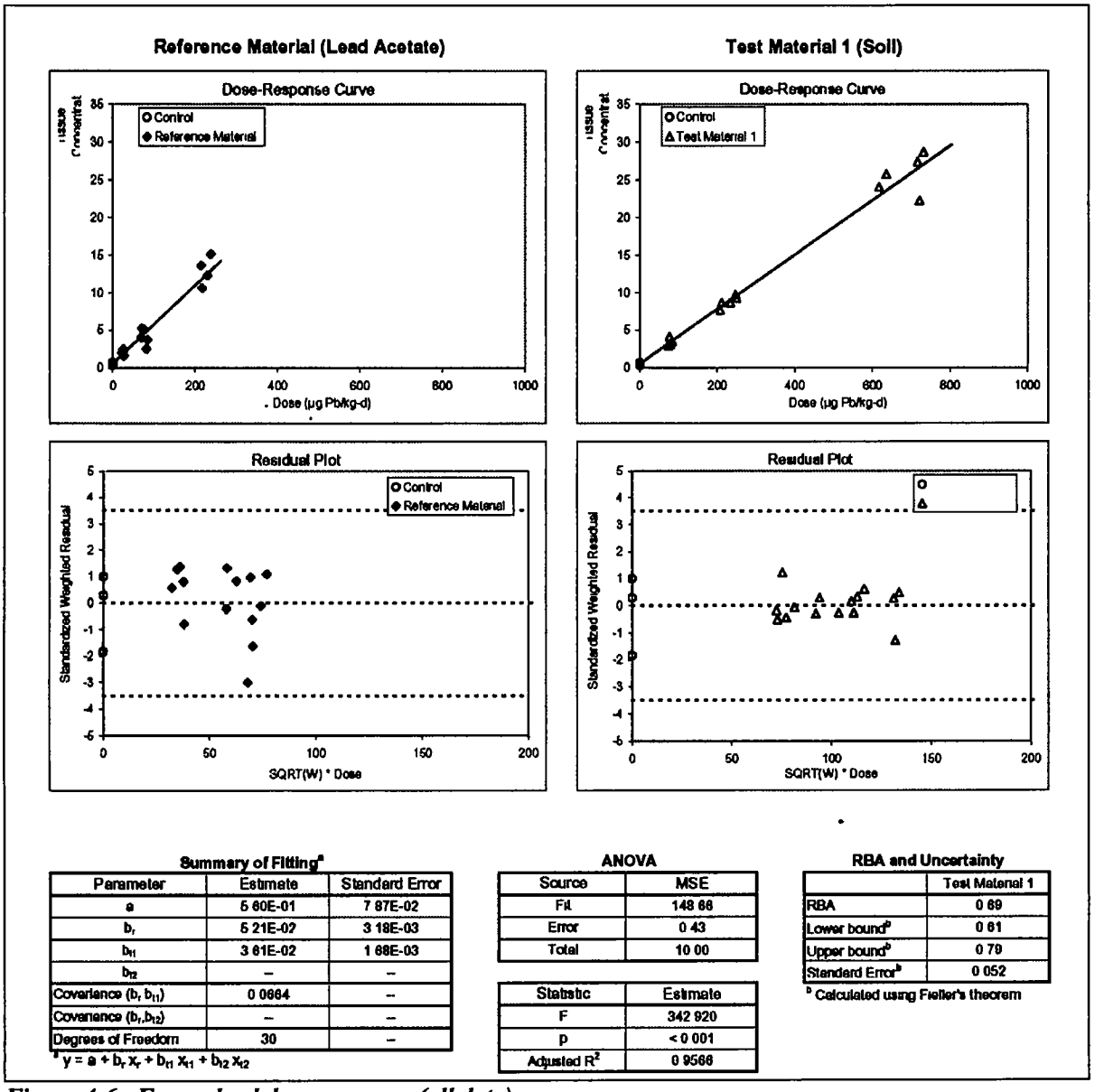
Statistic	Estimate
F	135 338
p	< 0 001
Adjusted R^2	0 8966

RBA and Uncertainty

	Test Material 1
RBA	0 84
Lower bound[b]	0 69
Upper bound[b]	1 04
Standard Error[b]	0 101

[b] Calculated using Fieller's theorem

Figure 4-5. Kidney lead dose-response (all data).



Summary of Fitting[a]

Parameter	Estimate	Standard Error
a	5 60E-01	7 87E-02
b_r	5 21E-02	3 18E-03
b_{t1}	3 61E-02	1 68E-03
b_{t2}	--	--
Covariance (b_r, b_{t1})	0 0664	--
Covariance (b_r,b_{t2})	--	--
Degrees of Freedom	30	--

[a] $y = a + b_r x_r + b_{t1} x_{t1} + b_{t2} x_{t2}$

ANOVA

Source	MSE
Fit	148 66
Error	0 43
Total	10 00

Statistic	Estimate
F	342 920
p	< 0 001
Adjusted R^2	0 9566

RBA and Uncertainty

	Test Material 1
RBA	0 69
Lower bound[b]	0 61
Upper bound[b]	0 79
Standard Error[b]	0 052

[b] Calculated using Fieller's theorem

Figure 4-6. Femur lead dose-response (all data).

Table 4-1. Summary of end-point specific RBA estimates.

Measurement Endpoint	Estimated Soil RBA (90% Confidence Interval)
Blood Lead AUC [a]	0 75 (0.62 – 0.93)
Liver Lead	1 01 (0.76 – 1 34)
Kidney Lead	0 84 (0.69 – 1.04)
Femur Lead	0.69 (0 61 – 0.79)
Point Estimate	0 82 (0.63 – 1 15)

Note [a] Blood AUC data were fit to the linear model.

As seen, using lead acetate as a relative frame of reference, the RBA estimate is approximately 82% for the test soil.

4.5 UNCERTAINTY

The bioavailability estimates above are subject to uncertainty that arises from several different sources. One source of uncertainty is the inherent biological variability between different animals in a dose group, which in turn causes variability in the amount of lead in the tissues of the exposed animals. This between-animal variability in response results in statistical uncertainty in the best-fit dose-response curves and, hence, uncertainty in the calculated values of RBA. Such statistical uncertainty is accounted for by the statistical models used above and is characterized by the uncertainty range around the endpoint-specific and the point estimate values of RBA.

However, there is also uncertainty in the extrapolation of RBA values measured in juvenile swine to young children or adults, and this uncertainty is not included in the statistical confidence bounds above. Even though the immature swine is believed to be a useful and meaningful animal model for gastrointestinal absorption in children, it is possible that there are differences in physiological parameters that may influence RBA and that RBA values in swine are not identical to values in children. In addition, RBA may depend on the amount and type of food in the stomach, since the presence of food can influence stomach pH, holding time, and possibly other factors that may influence lead solubilization. In this regard, it is important to recall that RBA values measured in this study are based on animals that have little or no food in their stomach at the time of lead exposure and, hence, are likely to yield high-end values of RBA. Thus, these RBA values may be somewhat conservative for humans who ingest the soils along with food. The magnitude of this bias is not known.

There were a few instances where some animals did not consume their entire dose (see Appendix A, Table A-3). During the study, however, the dosing technician observed each animal and attempted to estimate the fraction of dose not consumed; these estimates of missed doses were then used to adjust the time-weighted average dose calculation for each animal downward. Because these estimates of missed doses are subjective, they introduce some uncertainty; however, the magnitude of this uncertainty is thought to be small. All calculations are based on actual administered doses (not target doses) to compensate for dosing errors.

4.6 IN VITRO BIOACCESSIBILITY RESULTS

The summary of the in vitro bioaccessibility results is shown in Table 4-2. Lead ore concentrate samples were composited and prepared by Dr. Yang and submitted to Dr. Drexler. Dr. Drexler performed the in vitro extraction in triplicate on –250 μm materials.

Table 4-2. Summary of in vitro bioaccessibility results.

Sample ID	Weight of Sample	Solution pH prior to extraction	Solution pH after extraction	Pb concentration in <250 µm concentrate (mg/kg)	Calculated Total Pb in soil used (mg Pb)	Pb concentration in fluid following extraction (mg/L)	Amount of Solution (L)	% Relative Pb Bioaccessibility/ Availability
In Vitro Bioassay Results Summary using Dr Drexler's Lead Concentrations								
HER-2930-1	1 00021	1 54	1 57	2473	2 47	17 32	0.1	70
HER-2930-2	1 00036	1.54	1.57	2465	2 47	17 06	0.1	69
HER-2930-3	1.00036	1 54	1 57	2534	2.53	16 87	0 1	67
Mean ±standard deviation (n=3)								69±1 5
In Vitro Bioassay Results Summary using EPA's Average Bulk Lead Concentration								
HER-2930-1	1.00021	1.54	1.57	2021	2 01	17.32	0 1	86
HER-2930-2	1.00036	1 54	1 57	2021	2 02	17 06	0 1	84
HER-2930-3	1 00036	1.54	1.57	2021	2.02	16.87	0.1	83
Mean ±standard deviation (n=3)								85±1 1

5. DISCUSSION

The analytical results from Wilson (2003) characterize the test plot soils as follows: clay loam texture, slightly acidic (pH 6), low in organic matter (2.1 weight percent) and cation exchange capacity (11.6 meq/100g), plus being very low in total phosphorus (17 lbs/acre). The lead speciation studies performed by Johnson and Abraham (2002) indicate the ore concentrate particles have a geometric mean size of 1.6 µm, and that most of the lead occurs as galena (PbS). Using these data, and various assumptions as judged necessary (e.g., E_H in the +200 to 450 mV range), MSE prepared the following preliminary conceptual model of Pb weathering in the Herculaneum test plot soils.

The chemical reactions included in the model are as follows:

- $PbS(s) + H^+ \leftrightarrows Pb^{+2} + SH^-$;
- $SH^- + 4HOH \leftrightarrows SO_4^{-2} + 9H^+ + 8e^-$;
- $Pb^{+2} + SO_4^{-2} \leftrightarrows PbSO_4(s)$;
- $HCO_3^- + Pb^{+2} \leftrightarrows PbCO_3(s) + H^+$;
- $PbS(s) + H_2CO_3 + O_2 \rightarrow PbCO_3(s) + SO_4^{-2} + 2H^+$; and
- $5Pb^{+2} + 3H_2PO_4^- + Cl^- \rightarrow Pb_5(PO_4)_3Cl(s) + 6H^+$

Solid species of varying crystallinity are designated by "(s)", and all others occur as aqueous (dissolved) species. The first 2 equations do not address the mechanisms or varying rates of production and release of aqueous lead and sulfoxyanions; such details can be found in the papers by Chernyshova (2003), da Silva (2004), Fornasiero et al. (1994), plus Nowak and Laajalehto (2000). Essentially, it is suggested that oxidative dissolution of the small ore concentrate particles occurs very rapidly upon contact with soil (pore) water. da Silva (2004) observed that bacterial oxidation of galena particles < 45 µm in diameter resulted in complete conversion to lead sulfate in about 24 days at 35 °C. Assuming a 10-fold increase in

reaction rate for the Herculaneum particles and 100-fold decrease for cooler soil temperatures (i.e., 15 °C), the concentrate particles may be completely reacted within 240 days of incorporation into residential topsoil.

Given the relatively low organic matter level (i.e., about half that commonly seen in humid temperate soils; Brady, 1984), MSE assumes that only a small amount of the total Pb^{+2} is complexed to such organic ligands as humic acids. However, migration of aqueous Pb^{+2} into lower reaches of the soil profile may be slowed by ad(b)sorption to hydrous iron and manganese oxides (Morin et al., 1999). It is further suggested that persistence of solid Pb compounds is determined largely by their respective solubility product (K_{sp}) values; as the log K_{sp} values become more negative, the compounds become less soluble in water (at circumneutral pH and 25 °C). Thus, the solubility of anglesite ($PbSO_4$, –7.7) is > cerussite ($PbCO_3$, –12.8), which is >> chloropyromorphite [$Pb_5(PO_4)_3Cl$, –84.4] (Nriagu, 1994). The latter compound is probably the most environmentally stable and predominant form of solid Pb species in the Herculaneum test plot soils (Nriagu, 1974). This hypothesis is supported by the observations of Johnson and Abraham (2002) that lead phosphate particle types are predominant in residential soils, as well as by initial geochemical modeling performed by MSE.

The concentration data presented in Table 5-1 were input to the STABCAL model (Huang, 2002). Model output, shown in Figures 5-1 and 5-2, are very similar to those presented in Nriagu (1974; Figure 4-3) for roadside soils. Furthermore, lead carbonate and sulfate appear (in aqueous or solid forms) only in the complete absence of phosphorus; such cases are illustrated in Figures 5-3 through 5-5. These graphs are very similar to P-free stability diagrams found in the papers by Garrels (1954) and Sato (1992). In such instances a 1:1 molar ratio exists between anglesite and cerussite at pH 6 and 300 ± 100 mV (E_H).

Table 5-1. Summary of inputs to the STABCAL modeling exercise.

	Concentration (µg/L) in Soil Pore Water [a]	
Constituent	**Lower Bound**	**Upper Bound**
Cl^{-1}	2,000	10,000
$H_2CO_3^0$	6,500	7,100
HCO_3^{-1}	2,800	3,100
$H_2PO_4^{-1}$	5	50
Pb^{+2}	100	1,000
SO_4^{-2}	10,00	25,000

Note: [a] P_{CO2} is about 10-fold that of atmospheric levels, but represents concentrations expected in soil gas (Lindsay, 1979, Chapter 6) All other concentrations are based on best judgment by MSE

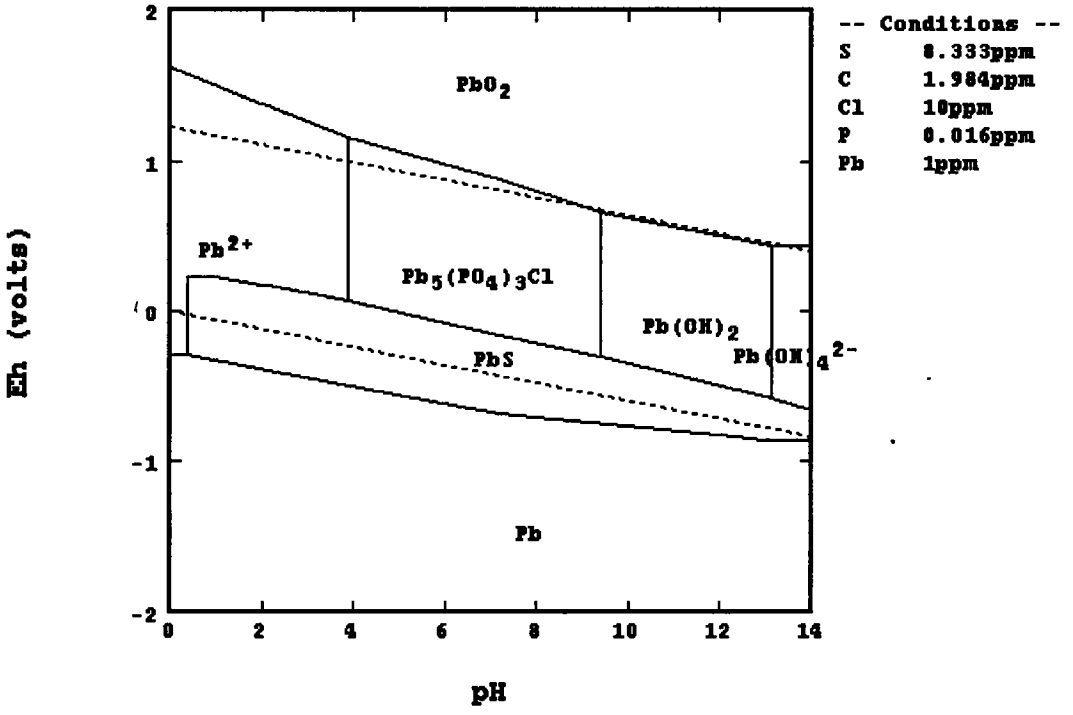


Figure 5-1. STABCAL model results for upper bound concentration limits.

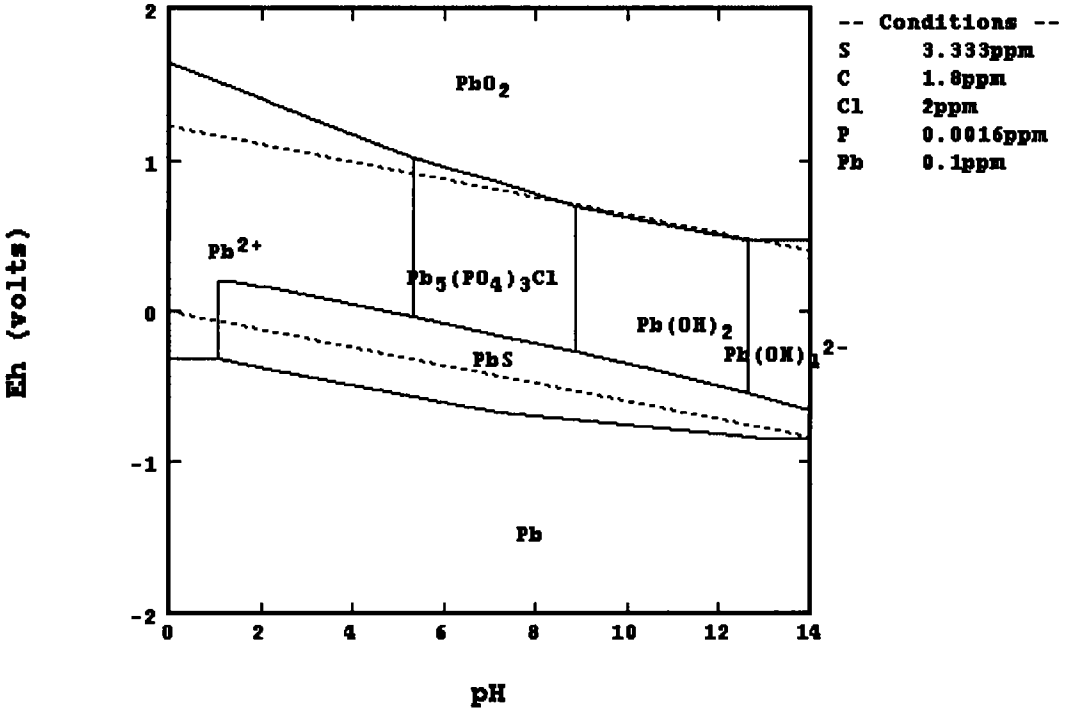


Figure 5-2. STABCAL model results for lower bound concentration limits.

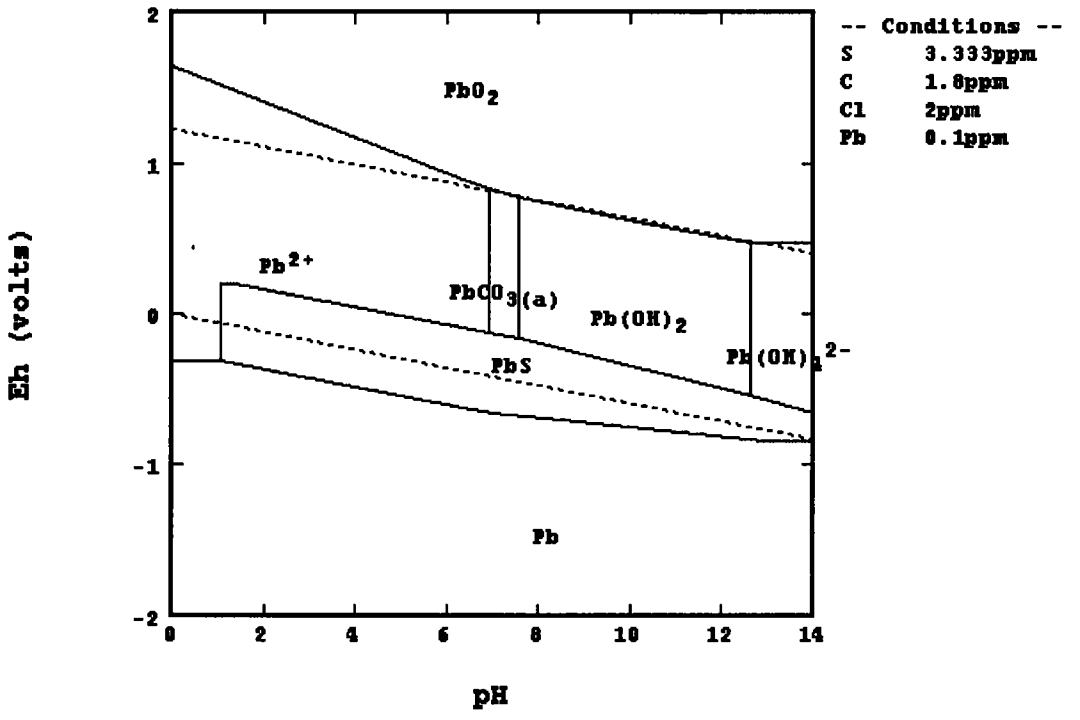


Figure 5-3. STABCAL model results for No-P, low-Pb case.

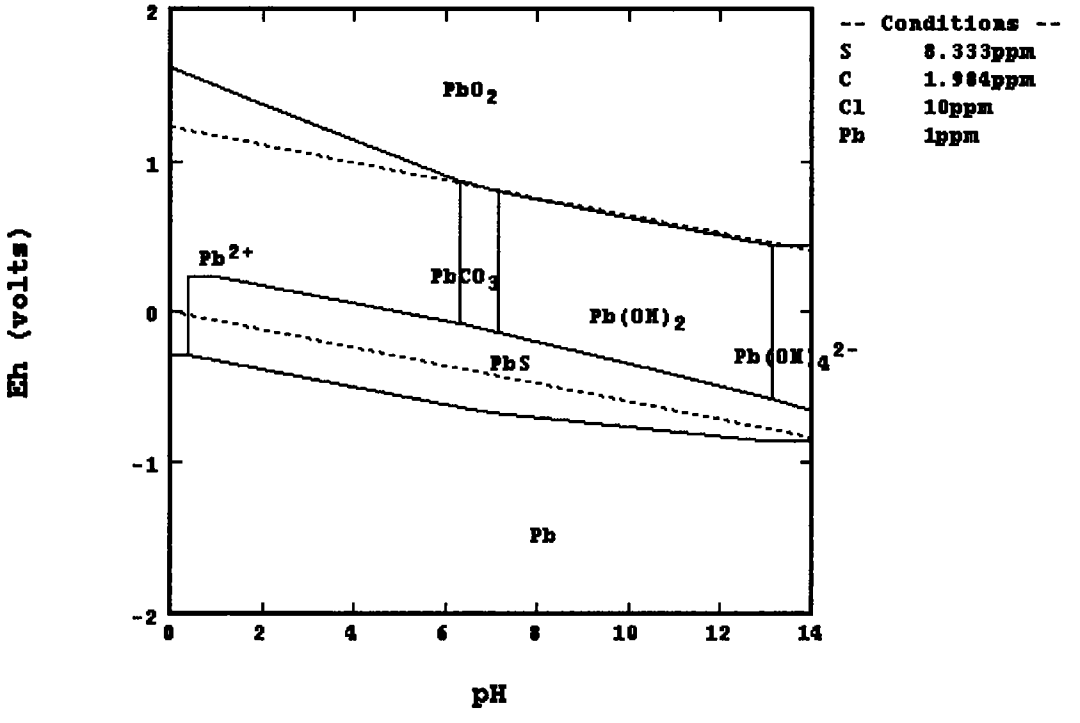


Figure 5-4. STABCAL model results for No-P, moderate-Pb case.

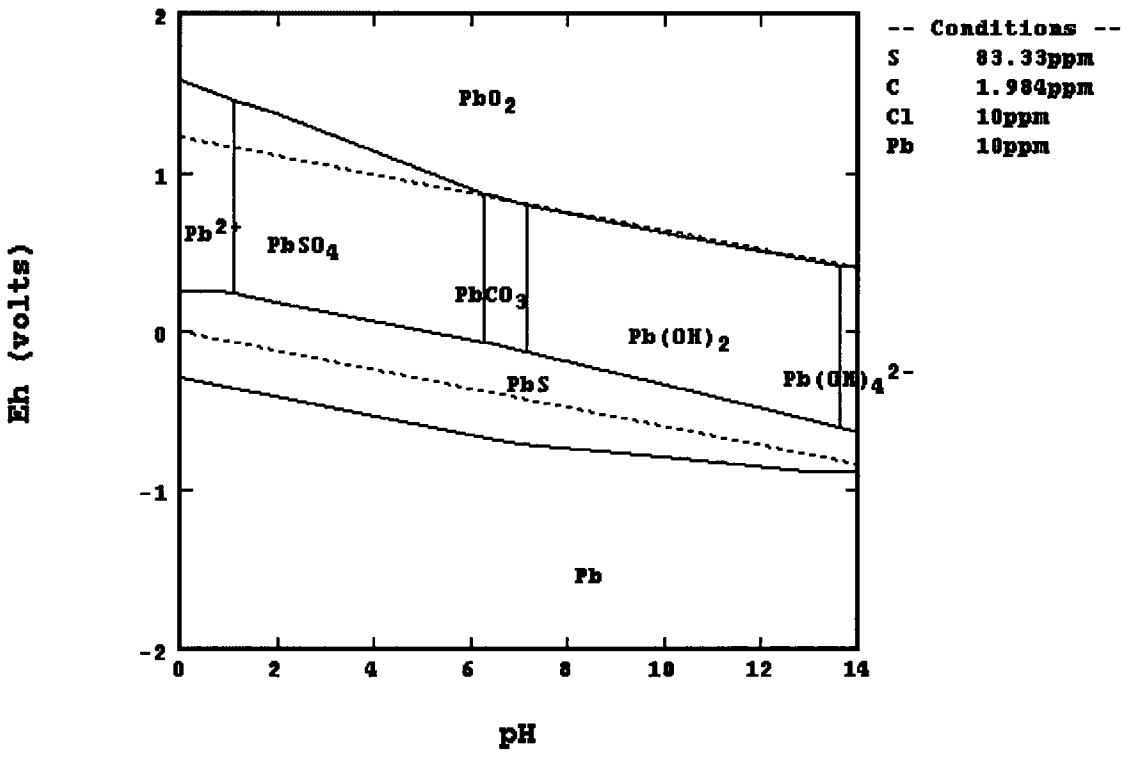


Figure 5-5. STABCAL model results for No-P, high-Pb case.

However, these STABCAL results must be interpreted carefully because:

- they do not address reaction-specific kinetics -- concentration-diffusion conditions may result in one reaction proceeding faster than the others (Langmuir, 1997); and
- they do not address the reversibility in the weathering of the solid Pb species (Sato, 1992).

These constraints are certainly relevant to using the model results for the interpretation of the Pb bioaccessibility (in vitro) and Pb-RBA (in vivo, swine) studies results. An example of this problem is discussed below.

The potential change in lead relative bioavailability (RBA) in concentrate-contaminated residential soils can be approximated by noting that Pb mass is independent of its RBA value. For example:

- addition of 500 mg of Pb having an RBA of 0.50 ($RBA_{0.5}$) to 1 kg of Pb-free soil results in 500 mg/kg of $RBA_{0.5}$ soil; while
- addition of another 500 mg of $RBA_{0.5}$ Pb to the above soil will double the Pb concentration (mass), but the $RBA_{0.5}$ remains the same unless the physicochemical state of the soil is changed.

Thus, there will be no change in RBA over time, even after adding the "new" source of Pb, if both materials have the same RBA value. Furthermore, initial bioavailability of Pb (RBA_0) can be approximated in Herculaneum soils as follows: $RBA_0 = RBA_1 - RBA_{PbS}$, where RBA_1 is the swine study result for the May 2005 soil and RBA_{PbS} = the estimated value for galena presented in Figure 2-7 of the

EPA (2004) report. Thus, $RBA_0 \cong 0.82 - 0.05 \cong 0.77$, which exceeds the estimated RBA for "undusted" residential soils (i.e., 0.45) from inspection of the USEPA (2004a) report.

Given MSE's modeling results (Figures 5-1 and 5-2) that show predominance of "lead phosphate", RBA_0 would be at least 0.45. Johnson and Abraham report (2002, Table IV) that many other forms of Pb probably exist in residential soils, as well as the presence of "lead oxide" in the ore concentrate sample. These observations suggest that other, more biologically available, forms of Pb are present in both the concentrate and in concentrate-contaminated soils. In both cases, formation of a cerussite coating on the pyromorphite particles could occur. Although the phosphate salt has a very low solubility, the surface : mass ratio is very high for the original galena particles. Meteoric water would supply a continuous, and potentially increasing, source of carbonic acid as it percolates through the soil profile. Lead oxide is more soluble (K_{sp} of –14.7) than pyromorphite compounds, and could form oxycarbonate [e.g., $Pb_3(CO_3)_2(OH)_2$] precipitates having similar solubilities to that of cerussite (Lindsay, 1979). The relative amounts of these various forms of Pb could be approximated by selective extraction methods (e.g., Chen et al., 2000; Basta and Gradwohl, 2000); such results would provide another "check" on the conceptual model's credibility.

The Phase 1 (May 2005 soil) in vitro and in vivo results of 0.69 and 0.82, respectively, probably reflect the effects of these more bioavailable Pb species on RBA of bulk soils. However, as such species (e.g., cerussite) would occur in "pre-dusted" and "dusted" residential soils, the change in RBA might be relatively small. For example, the percent change in RBA may be equal to ((0.82-0.77)/0.82) * 100 or 6% above background conditions. Given the intrinsic uncertainties in the Phase 1 in vivo results (Casteel et al., 2006; pp 14-15), it may be difficult to discern such a change with any degree of statistical confidence. Clearly, addition of more PbS-bearing fugitive particulate matter to residential soils is a matter of public health concern; however, the issue is more one of increased contamination levels than of increased RBA. Finally, the "pre-dust" Pb species mix may still be responding to ore concentrate addition, and further data are needed to evaluate the credibility of the MSE model. If the model is correct, then "equilibrium" has occurred and the RBA results for the Phase 2 (June 2006 soil) should be about the same – within experimental error – as observed to date. On the other hand, if Pb-RBA continues to climb, then this would indicate that "equilibrium" has not occurred; consequently, even more time-interval data would then be required to refine or replace the present model.

6. CONCLUSIONS AND RECOMMENDATIONS

When reliable site-specific data are lacking, the USEPA typically employs a default RBA value of 60% for lead in soil compared to soluble lead in water, for both children and adults. The RBA estimate of 82% for the test soil used in this study is higher than the default value of 60%, indicating that absorption of and hazards from lead in this soil may be higher than usually assumed. It is appropriate to take this into account when evaluating potential risks to humans from incidental ingestion of this soil.

MSE agrees with the conclusion in Casteel et al. (2006, p.15) that the soil/ore concentrate mixture exhibits an RBA that exceeds the IEUBK model default value of 60%. We also suggest that the Pb-RBA's point estimate of 82% is conservative. Interpolation of Dr. Drexler's average in vitro bioaccessability result (0.687+/- 0.015) into Figure 3-6 of the December 2004 USEPA report yields a "best estimate" of 66.6% for predicted Pb-RBA and a 95% UCL of 89.9%.

Tetra Tech's QAPP refers to a Pb speciation study by Johnson and Abraham (2002) that observed transformation of lead sulfide to lead sulfate and lead carbonate in soils. Given this observation and group-specific RBA values in the December 2004 USEPA report (Figure 2-7), an RBA in the 65% to

75% range appears reasonable for the 12-month soil sample in the current study. A 24-month soil sample is scheduled to be collected in May 2006 and an in vivo and in vitro study will be completed.

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APPENDIX A

Detailed Results from
Casteel et al. (2006)

TABLE A-1 SCHEDULE

Study Day	Day	Date	Bleed	Dose Administration	Feed Special Diet	Weigh	Dose Prep	Cull Pigs/ Assign Dose Group	Sacrifice/ Necropsy
-5	Wednesday	6/8/05			transition	X			
-4	Thursday	6/9/05			transition			X	
-3	Friday	6/10/05			X				
-2	Saturday	6/11/05			X				
-1	Sunday	6/12/05			X	X	X		
0	Monday	6/13/05	X	X	X				
1	Tuesday	6/14/05	X	X	X				
2	Wednesday	6/15/05	X	X	X	X	X		
3	Thursday	6/16/05	X	X	X				
4	Friday	6/17/05		X	X				
5	Saturday	6/18/05	X	X	X	X	X		
6	Sunday	6/19/05		X	X				
7	Monday	6/20/05	X	X	X				
8	Tuesday	6/21/05		X	X	X	X		
9	Wednesday	6/22/05	X	X	X				
10	Thursday	6/23/05		X	X				
11	Friday	6/24/05		X	X	X	X		
12	Saturday	6/25/05	X	X	X				
13	Sunday	6/26/05		X	X				
14	Monday	6/27/05		X	X	X			
15	Tuesday	6/28/05	X						X

MSE2_Appendix A xls (A-1_Schedule)

TABLE A-2 GROUP ASSIGNMENTS

Pig Number	Dose Group	Material Administered	Target Dose of Lead (µg/kg-day)
804 820 845	1	Control	3
802 803 816 826 838	2	Lead Acetate	25
819 832 834 839 846	3	Lead Acetate	75
801 806 823 835 850*	4	Lead Acetate	225
809 812 817 824 825	5	Test Material	75
813 830 831 833 844	6	Test Material	225
807 808 810 828 840	7	Test Material	675

*Pig 850 died during the study and was excluded from all analyses.

TABLE A-3 BODY WEIGHTS AND ACTUAL ADMINISTERED DOSES, BY DAY

Body weights were measured on days -1 2 5 8 11 and 14 Weights for other days are estimated based on linear interpolation between measured values

Group	Pig #	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7		Day 8		Day 9		Day 10		Day 11		Day 12		Day 13		Day 14		Days 0 14
		BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Pb Dose (ug/kg-d)	BW (kg)	Mean Pb Dose (ug/kg-d)
1	804	9 9	0 00	10 2	0 00	10 7	0 00	11 1	0 00	11 6	0 00	11 9	0 00	12 4	0 00	12 8	0 00	13 2	0 00	13 6	0 00	14 1	0 00	14 7	0 00	15 2	0 00	15 8	0 00	16 4	0 00	16 9	0 00	0 00
1	820	10 9	0 00	11 2	0 00	11 6	0 00	12 0	0 00	12 2	0 00	12 5	0 00	12 7	0 00	13 1	0 00	13 5	0 00	14 0	0 00	14 4	0 00	14 9	0 00	15 4	0 00	15 9	0 00	16 3	0 00	16 8	0 00	0 00
1	845	12 1	0 00	12 3	0 00	12 6	0 00	12 9	0 00	13 4	0 00	14 0	0 00	14 5	0 00	15 0	0 00	15 5	0 00	16 0	0 00	16 6	0 00	17 2	0 00	17 8	0 00	18 2	0 00	18 7	0 00	19 1	0 00	0 00
2	802	10 9	0 00	11 1	27 16	11 3	26 65	11 5	26 13	12 0	24 67	12 4	23 71	12 9	24 81	13 3	24 17	13 8	23 38	14 3	24 48	14 8	25 64	15 4	24 72	16 0	23 87	16 6	23 53	17 1	24 66	17 7	23 84	25 09
2	803	11 0	0 00	11 3	26 69	11 7	26 79	12 0	25 64	12 3	25 84	12 7	25 16	13 0	24 62	13 3	19 66	13 6	24 63	13 9	25 07	14 5	26 11	15 2	26 62	15 8	24 62	16 3	24 39	16 7	22 60	29 2	29 88	24 26
2	816	10 1	0 00	10 4	28 80	10 8	27 91	11 1	27 67	11 5	27 76	11 9	26 96	12 3	28 62	12 0	27 69	13 0	26 77	13 4	26 01	13 9	27 27	14 4	26 29	15 0	25 39	15 6	27 29	16 0	26 32	16 5	26 60	26 99
2	826	12 7	0 00	12 7	23 63	12 8	23 41	12 9	23 39	13 4	23 88	13 9	23 01	14 4	22 21	14 9	23 39	15 5	22 58	16 0	21 78	16 4	23 00	16 9	19 88	17 3	21 94	17 8	23 66	18 3	23 03	18 8	22 44	23 04
2	838	10 4	0 00	10 8	27 82	11 1	27 76	11 3	26 89	11 9	27 44	11 9	26 71	12 3	26 46	12 8	27 62	13 0	26 84	13 4	26 10	14 0	27 17	14 6	26 42	15 2	24 97	15 7	24 74	16 3	25 97	16 8	25 04	26 97
3	819	12 5	0 00	12 9	71 34	13 2	68 38	13 6	67 58	14 1	71 28	14 7	68 88	15 2	66 12	15 5	70 47	15 8	69 04	16 2	67 71	16 7	71 41	17 3	69 13	17 8	68 93	18 3	72 28	18 8	70 42	19 3	68 85	69 46
3	852	11 4	0 00	11 9	77 38	12 3	74 46	12 8	71 85	13 0	77 21	13 3	75 64	13 6	74 17	14 0	76 11	14 5	76 67	14 9	73 39	15 5	77 10	16 0	74 83	16 4	72 65	17 1	77 21	17 7	74 73	18 3	72 41	76 18
3	854	10 3	0 00	10 6	86 26	11 0	83 38	11 4	84 68	11 7	86 27	12 0	84 19	12 3	82 04	12 8	86 32	13 4	81 71	14 0	78 39	14 5	82 16	15 1	79 66	15 7	76 20	16 2	81 06	16 7	79 05	17 3	76 61	82 12
3	839	12 2	0 00	12 6	72 77	13 0	70 62	13 4	68 69	13 8	72 65	14 3	70 29	14 8	67 91	15 3	71 70	15 7	69 66	16 2	67 71	16 9	71 12	17 4	68 60	18 0	66 25	18 6	71 18	19 1	68 97	19 7	67 08	69 93
3	846	9 7	0 00	10 1	94 37	10 6	88 86	11 0	89 25	11 4	88 42	11 7	85 66	12 1	83 46	12 5	87 36	12 9	84 58	13 4	81 91	13 9	85 69	14 5	82 15	15 1	78 97	15 6	84 71	16 1	82 08	16 6	79 61	84 89
4	801	10 1	0 00	10 6	243 98	11 0	234 00	11 5	224 80	11 8	239 26	12 1	232 60	12 6	224 46	13 0	234 95	13 5	224 96	14 0	217 61	14 6	230 26	15 1	221 87	15 7	214 67	16 2	229 48	16 7	23 L84	17 3	224 67	231 31
4	804	11 2	0 00	11 5	223 18	11 9	216 81	12 2	210 88	12 6	223 45	13 0	216 31	13 5	209 61	13 9	219 06	14 3	213 78	14 7	207 95	15 2	216 63	15 8	211 62	16 4	204 29	17 4	222 74	18 4	210 63	19 4	199 77	214 61
4	823	11 2	0 00	11 5	223 18	11 9	216 00	12 3	209 27	12 7	221 09	13 1	215 21	13 5	208 83	13 9	219 44	14 3	213 64	14 7	207 96	15 2	220 80	15 7	213 62	16 2	206 81	16 7	232 31	17 2	225 76	17 7	219 58	217 76
4	835	9 6	0 00	9 9	260 88	10 2	252 77	10 6	245 14	10 7	262 66	11 0	257 97	11 2	251 72	11 8	257 81	12 4	246 03	13 1	233 45	14 3	235 11	15 6	218 84	16 7	201 22	17 3	224 46	17 9	210 72	18 6	200 49	243 10
4	850*																																	
5	806	10 5	0 00	10 7	77 86	10 8	76 81	11 0	76 76	11 6	76 46	12 1	72 87	12 7	69 69	12 9	74 92	13 2	72 32	13 6	71 76	14 0	74 94	14 6	72 48	15 0	70 13	15 3	76 26	15 7	73 44	16 1	71 69	74 16
5	812	9 7	0 00	9 9	83 66	10 2	81 46	10 5	79 36	10 6	82 84	10 8	81 06	11 0	80 41	11 3	84 19	11 6	83 80	11 9	81 77	12 3	85 58	12 7	82 69	13 1	80 34	13 6	85 16	14 1	82 16	14 6	79 33	82 33
5	817	10 9	0 00	10 2	81 16	10 4	79 89	10 7	77 88	11 0	80 37	11 3	77 81	11 7	75 68	12 0	80 83	12 4	78 04	12 8	76 70	13 2	79 23	13 7	76 72	14 1	74 36	14 4	80 06	14 7	78 34	15 1	76 69	78 48
5	824	10 3	0 00	10 4	79 63	10 6	78 78	10 7	77 88	11 1	79 68	11 5	74 89	11 9	74 39	12 2	78 21	12 6	76 80	13 0	74 54	13 6	77 57	14 0	74 71	14 6	72 06	15 1	76 62	15 6	73 91	16 2	71 47	76 63
5	825	9 8	0 00	10 2	81 96	10 6	78 13	11 0	78 41	11 5	76 57	12 0	73 38	12 5	70 44	12 9	75 62	13 3	72 58	13 8	70 47	14 3	73 48	14 8	70 62	15 3	68 53	15 8	73 29	16 2	71 35	16 7	69 32	73 82
6	813	9 6	0 00	10 0	264 91	10 3	256 41	10 7	244 66	11 0	256 26	11 3	248 03	11 8	242 73	12 0	256 67	12 4	247 71	12 9	239 36	13 4	252 87	14 0	242 90	14 5	233 69	15 1	247 13	15 6	238 41	16 2	230 29	247 77
6	830	9 7	0 00	9 8	269 49	10 0	263 49	10 2	256 76	10 6	263 85	11 1	253 33	11 5	243 78	12 0	256 67	12 6	244 72	13 0	237 61	13 4	252 25	13 9	243 49	14 4	236 31	15 0	248 23	15 6	239 92	16 2	230 29	259 91
6	831	11 8	0 00	12 1	218 42	12 4	213 42	12 7	208 64	13 1	214 28	13 6	207 41	14 0	200 97	14 5	212 12	15 1	204 37	15 6	197 16	16 1	210 66	16 6	204 64	17 1	198 74	17 7	210 72	18 3	203 79	18 9	197 31	207 36
6	833	11 7	0 00	12 0	219 94	12 3	214 87	12 8	209 46	13 0	215 05	13 4	209 22	13 8	203 16	14 3	215 04	14 7	208 23	15 2	203 02	15 8	217 21	16 1	211 12	16 6	206 36	17 1	218 14	17 6	211 32	18 2	204 92	211 21
6	844	10 9	0 00	11 0	240 39	11 1	238 49	11 2	234 70	11 6	241 33	12 1	232 61	12 6	223 39	13 0	237 61	13 4	230 39	13 8	223 49	14 2	238 07	14 7	230 26	15 2	222 93	15 6	236 41	16 0	229 46	16 4	224 78	233 46
7	807	10 3	0 00	10 7	765 23	11 1	739 36	11 6	712 87	11 9	752 83	12 3	729 11	12 7	707 02	13 2	741 56	13 8	711 08	14 4	683 66	14 9	718 16	15 1	704 29	15 6	690 40	14 9	718 16	15 1	704 64	17 1	690 92	722 71
7	808	10 3	0 00	10 7	764 66	11 2	738 74	11 7	709 39	11 9	750 62	12 2	734 10	12 6	716 37	12 9	750 77	13 4	734 16	13 8	710 22	14 2	751 06	14 6	736 48	15 0	711 00	15 5	749 90	16 1	734 71	16 6	701 43	731 87
7	810	10 4	0 00	10 9	752 94	11 4	720 82	11 9	691 82	12 3	730 10	12 7	707 02	13 1	686 34	13 9	739 70	13 5	718 70	13 7	718 02	14 3	748 80	15 0	713 38	15 6	682 65	16 0	729 35	16 3	712 89	16 7	697 23	717 99
7	828	12 6	0 00	12 8	649 20	13 2	625 16	13 6	607 09	14 0	641 13	14 4	621 09	14 9	602 27	15 3	641 29	15 7	623 61	16 2	606 45	17 4	612 34	18 1	590 86	18 7	624 33	19 3	604 97	19 9	586 69	615 63
7	840	12 4	0 00	12 5	656 44	12 6	649 80	12 8	642 71	13 4	669 11	14 0	639 80	14 6	612 59	15 1	649 79	15 6	629 61	16 1	610 65	16 5	648 08	17 0	626 74	17 6	608 43	17 9	648 28	18 4	633 96	19 0	619 38	636 86

*Pig 850 died during the study and was excluded from all analyses

Inacceptable Doses
Day 6 - Pig 803 did not eat entire AM dose (ate approximately 80%) Daily dose adjusted to 78%
Day 10 Pig 826 did not eat entire AM dose (ate approximately 76%) Daily dose adjusted to 87 5%
Day 4 - Pig 844 dropped approximately half its dose on the ground the dropped portion was noted to the animal around 11 00 AM No dose adjustment was made (daily dose remained 100%)

TABLE A-4 ANIMAL HEALTH

Naxcel Treatment for Illness

First Day of Treatment	Treatment Notes*	Pig	Group	Indications
Day -4 (6/09/05)	Treatment duration = 7 days	801	4	Elevated temperature, coughing, anorectic
Day 1 (6/14/05)	Treatment began at 7 PM	844	6	Elevated temperature, anorectic at PM feeding
		809	5	
Day 2 (6/15/05)	Treatment began in PM	820	1	Elevated temperature, diarrhea
Day 4 (6/17/05)		812	5	Elevated temperature, diarrhea
		817	5	
		826	2	
		835	4	Vomiting in morning
Day 6 (6/19/05)	Treatment began at 12 PM	806	4	Elevated temperature, didn't eat all of AM feed
Day 8 (6/21/05)	1.3 mL Naxcel administered	808	7	Elevated temperature, diarrhea in AM
Day 10 (6/23/05)	1 5 mL Naxcel administered	807	7	Elevated temperature
Day 13 (6/26/05)	1 5 mL Naxcel administered	840	7	Elevated temperature, diarrhea

*Treatment consisted of 1cc/10kg body weight of Naxcel for a duration of 3 days, unless otherwise noted.

Animal Deaths

Pig 850 (Group 4) was found dead in on Day 11 (6/24/05), he had shown no signs of inappetance or diarrhea Bacteriology of necropsy samples indicated *Salmonella*.

TABLE A-5

LEAD ANALYTICAL RESULTS FOR STUDY SAMPLES

Sample Number	Tag Number	Matrix	Group	Material Administered	Target Dose (ug/kg-d)	Pig Number	Collection Day	Actual Dose (ug/d)	Actual BWAdj Dose (ug/d)	Q	Pb Conc	DL	AdjConc	Units
MSE2-804-(0)-B	MSE2-129	blood	1	Control	0	804	0	0	0	<	1	1	0.5	ug/dL
MSE2-820-(0)-B	MSE2-122	blood	1	Control	0	820	0	0	0	<	1	1	0.5	ug/dL
MSE2-845-(0)-B	MSE2-106	blood	1	Control	0	845	0	0	0	<	1	1	0.5	ug/dL
MSE2-802-(0)-B	MSE2-120	blood	2	Lead Acetate	25	802	0	300.5	27.15	<	1	1	0.5	ug/dL
MSE2-803-(0)-B	MSE2-133	blood	2	Lead Acetate	25	803	0	300.5	26.59	<	1	1	0.5	ug/dL
MSE2-816-(0)-B	MSE2-126	blood	2	Lead Acetate	25	816	0	300.5	28.8	<	1	1	0.5	ug/dL
MSE2-826-(0)-B	MSE2-113	blood	2	Lead Acetate	25	826	0	300.5	23.63	<	1	1	0.5	ug/dL
MSE2-838-(0)-B	MSE2-118	blood	2	Lead Acetate	25	838	0	300.5	27.82	<	1	1	0.5	ug/dL
MSE2-832-(0)-B	MSE2-125	blood	3	Lead Acetate	75	832	0	915.75	77.28	<	1	1	0.5	ug/dL
MSE2-834-(0)-B	MSE2-104	blood	3	Lead Acetate	75	834	0	915.75	86.26	<	1	1	0.5	ug/dL
MSE2-839-(0)-B	MSE2-135	blood	3	Lead Acetate	75	839	0	915.75	72.77	<	1	1	0.5	ug/dL
MSE2-846-(0)-B	MSE2-109	blood	3	Lead Acetate	75	846	0	915.75	90.37	<	1	1	0.5	ug/dL
MSE2-819-(0)-B	MSE2-115	blood	3	Lead Acetate	75	819	0	915.75	71.26	<	1	1	0.5	ug/dL
MSE2-801-(0)-B	MSE2-132	blood	4	Lead Acetate	225	801	0	2574	243.98	<	1	1	0.5	ug/dL
MSE2-806-(0)-B	MSE2-130	blood	4	Lead Acetate	225	806	0	2574	223.18	<	1	1	0.5	ug/dL
MSE2-823-(0)-B	MSE2-123	blood	4	Lead Acetate	225	823	0	2574	223.18	<	1	1	0.5	ug/dL
MSE2-835-(0)-B	MSE2-102	blood	4	Lead Acetate	225	835	0	2574	260.88	<	1	1	0.5	ug/dL
MSE2-850-(0)-B	MSE2-103	blood	4	Lead Acetate	225	850	0	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-809-(0)-B	MSE2-114	blood	5	Soil	75	809	0	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-812-(0)-B	MSE2-108	blood	5	Soil	75	812	0	2574	259.56	<	1	1	0.5	ug/dL
MSE2-817-(0)-B	MSE2-136	blood	5	Soil	75	817	0	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-824-(0)-B	MSE2-111	blood	5	Soil	75	824	0	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-825-(0)-B	MSE2-105	blood	5	Soil	75	825	0	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-813-(0)-B	MSE2-112	blood	6	Soil	225	813	0	2.64	0.26	<	1	1	0.5	ug/dL
MSE2-830-(0)-B	MSE2-117	blood	6	Soil	225	830	0	2.64	0.27	<	1	1	0.5	ug/dL
MSE2-831-(0)-B	MSE2-131	blood	6	Soil	225	831	0	2.64	0.22	<	1	1	0.5	ug/dL
MSE2-833-(0)-B	MSE2-110	blood	6	Soil	225	833	0	2.64	0.22	<	1	1	0.5	ug/dL
MSE2-844-(0)-B	MSE2-119	blood	6	Soil	225	844	0	2.64	0.24	<	1	1	0.5	ug/dL
MSE2-807-(0)-B	MSE2-121	blood	7	Soil	675	807	0	8.19	0.77	<	1	1	0.5	ug/dL
MSE2-808-(0)-B	MSE2-127	blood	7	Soil	675	808	0	8.19	0.76	<	1	1	0.5	ug/dL
MSE2-810-(0)-B	MSE2-101	blood	7	Soil	675	810	0	8.19	0.75	<	1	1	0.5	ug/dL
MSE2-828-(0)-B	MSE2-107	blood	7	Soil	675	828	0	8.19	0.64	<	1	1	0.5	ug/dL
MSE2-840-(0)-B	MSE2-124	blood	7	Soil	675	840	0	8.19	0.66	<	1	1	0.5	ug/dL
MSE2-804-(1)-B	MSE2-149	blood	1	Control	0	804	1	0	0	<	1	1	0.5	ug/dL
MSE2-820-(1)-B	MSE2-144	blood	1	Control	0	820	1	0	0	<	1	1	0.5	ug/dL
MSE2-845-(1)-B	MSE2-140	blood	1	Control	0	845	1	0	0	<	1	1	0.5	ug/dL
MSE2-802-(1)-B	MSE2-152	blood	2	Lead Acetate	25	802	1	300.5	26.63	<	1	1	0.5	ug/dL
MSE2-803-(1)-B	MSE2-148	blood	2	Lead Acetate	25	803	1	300.5	25.79	<	1	1	0.5	ug/dL
MSE2-816-(1)-B	MSE2-175	blood	2	Lead Acetate	25	816	1	300.5	27.91	<	1	1	0.5	ug/dL
MSE2-826-(1)-B	MSE2-142	blood	2	Lead Acetate	25	826	1	300.5	23.51	<	1	1	0.5	ug/dL
MSE2-838-(1)-B	MSE2-158	blood	2	Lead Acetate	25	838	1	300.5	27.19	<	1	1	0.5	ug/dL
MSE2-819-(1)-B	MSE2-160	blood	3	Lead Acetate	75	819	1	915.75	69.38	<	1	1	0.5	ug/dL
MSE2-832-(1)-B	MSE2-157	blood	3	Lead Acetate	75	832	1	915.75	74.45		1	1	1	ug/dL
MSE2-834-(1)-B	MSE2-150	blood	3	Lead Acetate	75	834	1	915.75	83.38	<	1	1	0.5	ug/dL
MSE2-839-(1)-B	MSE2-145	blood	3	Lead Acetate	75	839	1	915.75	70.62		1	1	1	ug/dL
MSE2-846-(1)-B	MSE2-146	blood	3	Lead Acetate	75	846	1	915.75	86.66	<	1	1	0.5	ug/dL
MSE2-801-(1)-B	MSE2-165	blood	4	Lead Acetate	225	801	1	2574	234		3	1	3	ug/dL
MSE2-806-(1)-B	MSE2-164	blood	4	Lead Acetate	225	806	1	2574	216.91		2	1	2	ug/dL
MSE2-823-(1)-B	MSE2-163	blood	4	Lead Acetate	225	823	1	2574	216		3	1	3	ug/dL
MSE2-835-(1)-B	MSE2-166	blood	4	Lead Acetate	225	835	1	2574	252.77		3	1	3	ug/dL
MSE2-850-(1)-B	MSE2-153	blood	4	Lead Acetate	225	850	1	0.83	0.08		4	1	4	ug/dL
MSE2-809-(1)-B	MSE2-156	blood	5	Soil	75	809	1	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-812-(1)-B	MSE2-174	blood	5	Soil	75	812	1	2574	252.77	<	1	1	0.5	ug/dL
MSE2-817-(1)-B	MSE2-176	blood	5	Soil	75	817	1	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-824-(1)-B	MSE2-169	blood	5	Soil	75	824	1	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-825-(1)-B	MSE2-151	blood	5	Soil	75	825	1	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-813-(1)-B	MSE2-139	blood	6	Soil	225	813	1	2.64	0.26		2	1	2	ug/dL
MSE2-830-(1)-B	MSE2-168	blood	6	Soil	225	830	1	2.64	0.26	<	1	1	0.5	ug/dL
MSE2-831-(1)-B	MSE2-143	blood	6	Soil	225	831	1	2.64	0.21		1	1	1	ug/dL
MSE2-833-(1)-B	MSE2-154	blood	6	Soil	225	833	1	2.64	0.21		2	1	2	ug/dL
MSE2-844-(1)-B	MSE2-171	blood	6	Soil	225	844	1	2.64	0.24	<	1	1	0.5	ug/dL
MSE2-807-(1)-B	MSE2-173	blood	7	Soil	675	807	1	8.19	0.74		6	1	6	ug/dL
MSE2-808-(1)-B	MSE2-167	blood	7	Soil	675	808	1	8.19	0.73		6	1	6	ug/dL
MSE2-810-(1)-B	MSE2-170	blood	7	Soil	675	810	1	8.19	0.72		5	1	5	ug/dL
MSE2-828-(1)-B	MSE2-155	blood	7	Soil	675	828	1	8.19	0.62		6	1	6	ug/dL
MSE2-840-(1)-B	MSE2-161	blood	7	Soil	675	840	1	8.19	0.65		8	1	8	ug/dL
MSE2-804-(2)-B	MSE2-194	blood	1	Control	0	804	2	0	0	<	1	1	0.5	ug/dL
MSE2-820-(2)-B	MSE2-180	blood	1	Control	0	820	2	0	0	<	1	1	0.5	ug/dL
MSE2-845-(2)-B	MSE2-179	blood	1	Control	0	845	2	0	0	<	1	1	0.5	ug/dL
MSE2-802-(2)-B	MSE2-203	blood	2	Lead Acetate	25	802	2	300.5	26.13	<	1	1	0.5	ug/dL
MSE2-803-(2)-B	MSE2-183	blood	2	Lead Acetate	25	803	2	300.5	25.04	<	1	1	0.5	ug/dL
MSE2-816-(2)-B	MSE2-204	blood	2	Lead Acetate	25	816	2	300.5	27.07	<	1	1	0.5	ug/dL
MSE2-826-(2)-B	MSE2-188	blood	2	Lead Acetate	25	826	2	300.5	23.39	<	1	1	0.5	ug/dL
MSE2-838-(2)-B	MSE2-211	blood	2	Lead Acetate	25	838	2	300.5	26.59	<	1	1	0.5	ug/dL
MSE2-819-(2)-B	MSE2-205	blood	3	Lead Acetate	75	819	2	915.75	67.58	<	1	1	0.5	ug/dL
MSE2-832-(2)-B	MSE2-177	blood	3	Lead Acetate	75	832	2	915.75	71.82		1	1	1	ug/dL

TABLE A-5

Sample Number	Tag Number	Matrix	Group	Material Administered	Target Dose (ug/kg-d)	Pig Number	Collection Day	Actual Dose (ug/d)	Actual BWAdj Dose (ug/d)	Q	Pb Conc	DL	AdjConc	Units
MSE2-834-(2)-B	MSE2-210	blood	3	Lead Acetate	75	834	2	915.75	80.68		1	1	1	ug/dL
MSE2-839-(2)-B	MSE2-195	blood	3	Lead Acetate	75	839	2	915.75	68.6		1	1	1	ug/dL
MSE2-846-(2)-B	MSE2-201	blood	3	Lead Acetate	75	846	2	915.75	83.25		1	1	1	ug/dL
MSE2-801-(2)-B	MSE2-181	blood	4	Lead Acetate	225	801	2	2574	224.8		3	1	3	ug/dL
MSE2-806-(2)-B	MSE2-214	blood	4	Lead Acetate	225	806	2	2574	210.98		3	1	3	ug/dL
MSE2-823-(2)-B	MSE2-182	blood	4	Lead Acetate	225	823	2	2574	209.27		4	1	4	ug/dL
MSE2-835-(2)-B	MSE2-197	blood	4	Lead Acetate	225	835	2	2574	245.14		3	1	3	ug/dL
MSE2-850-(2)-B	MSE2-213	blood	4	Lead Acetate	225	850	2	0.83	0.07		4	1	4	ug/dL
MSE2-809-(2)-B	MSE2-184	blood	5	Soil	75	809	2	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-812-(2)-B	MSE2-206	blood	5	Soil	75	812	2	2574	246.32	<	1	1	0.5	ug/dL
MSE2-817-(2)-B	MSE2-199	blood	5	Soil	75	817	2	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-824-(2)-B	MSE2-187	blood	5	Soil	75	824	2	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-825-(2)-B	MSE2-185	blood	5	Soil	75	825	2	0.83	0.08	<	1	1	0.5	ug/dL
MSE2-813-(2)-B	MSE2-196	blood	6	Soil	225	813	2	2.64	0.25		2	1	2	ug/dL
MSE2-830-(2)-B	MSE2-200	blood	6	Soil	225	830	2	2.64	0.26		2	1	2	ug/dL
MSE2-831-(2)-B	MSE2-178	blood	6	Soil	225	831	2	2.64	0.21		2	1	2	ug/dL
MSE2-833-(2)-B	MSE2-186	blood	6	Soil	225	833	2	2.64	0.21		3	1	3	ug/dL
MSE2-844-(2)-B	MSE2-202	blood	6	Soil	225	844	2	2.64	0.24	<	1	1	0.5	ug/dL
MSE2-807-(2)-B	MSE2-208	blood	7	Soil	675	807	2	8.19	0.71		6	1	6	ug/dL
MSE2-808-(2)-B	MSE2-209	blood	7	Soil	675	808	2	8.19	0.7		7	1	7	ug/dL
MSE2-810-(2)-B	MSE2-207	blood	7	Soil	675	810	2	8.19	0.69		7	1	7	ug/dL
MSE2-828-(2)-B	MSE2-192	blood	7	Soil	675	828	2	8.19	0.61		7	1	7	ug/dL
MSE2-840-(2)-B	MSE2-191	blood	7	Soil	675	840	2	8.19	0.64		8	1	8	ug/dL
MSE2-804-(3)-B	MSE2-241	blood	1	Control	0	804	3	0	0	<	1	1	0.5	ug/dL
MSE2-820-(3)-B	MSE2-220	blood	1	Control	0	820	3	0	0	<	1	1	0.5	ug/dL
MSE2-845-(3)-B	MSE2-222	blood	1	Control	0	845	3	0	0	<	1	1	0.5	ug/dL
MSE2-802-(3)-B	MSE2-231	blood	2	Lead Acetate	25	802	3	318.75	26.67	<	1	1	0.5	ug/dL
MSE2-803-(3)-B	MSE2-224	blood	2	Lead Acetate	25	803	3	318.75	25.84	<	1	1	0.5	ug/dL
MSE2-816-(3)-B	MSE2-236	blood	2	Lead Acetate	25	816	3	318.75	27.76	<	1	1	0.5	ug/dL
MSE2-826-(3)-B	MSE2-246	blood	2	Lead Acetate	25	826	3	318.75	23.88	<	1	1	0.5	ug/dL
MSE2-838-(3)-B	MSE2-240	blood	2	Lead Acetate	25	838	3	318.75	27.44	<	1	1	0.5	ug/dL
MSE2-819-(3)-B	MSE2-250	blood	3	Lead Acetate	75	819	3	1005	71.28	<	1	1	0.5	ug/dL
MSE2-832-(3)-B	MSE2-238	blood	3	Lead Acetate	75	832	3	1005	77.21	<	1	1	0.5	ug/dL
MSE2-834-(3)-B	MSE2-229	blood	3	Lead Acetate	75	834	3	1005	86.27		2	1	2	ug/dL
MSE2-839-(3)-B	MSE2-219	blood	3	Lead Acetate	75	839	3	1005	72.65		2	1	2	ug/dL
MSE2-846-(3)-B	MSE2-221	blood	3	Lead Acetate	75	846	3	1005	88.42		2	1	2	ug/dL
MSE2-801-(3)-B	MSE2-237	blood	4	Lead Acetate	225	801	3	2819.25	239.26		2	1	2	ug/dL
MSE2-806-(3)-B	MSE2-239	blood	4	Lead Acetate	225	806	3	2819.25	223.45		2	1	2	ug/dL
MSE2-823-(3)-B	MSE2-227	blood	4	Lead Acetate	225	823	3	2819.25	221.99		3	1	3	ug/dL
MSE2-835-(3)-B	MSE2-244	blood	4	Lead Acetate	225	835	3	2819.25	262.66		3	1	3	ug/dL
MSE2-850-(3)-B	MSE2-251	blood	4	Lead Acetate	225	850	3	0.88	0.08		3	1	3	ug/dL
MSE2-809-(3)-B	MSE2-226	blood	5	Soil	75	809	3	0.88	0.08		1	1	1	ug/dL
MSE2-812-(3)-B	MSE2-225	blood	5	Soil	75	812	3	2819.25	265.55	<	1	1	0.5	ug/dL
MSE2-817-(3)-B	MSE2-223	blood	5	Soil	75	817	3	0.88	0.08	<	1	1	0.5	ug/dL
MSE2-824-(3)-B	MSE2-243	blood	5	Soil	75	824	3	0.88	0.08	<	1	1	0.5	ug/dL
MSE2-825-(3)-B	MSE2-234	blood	5	Soil	75	825	3	0.88	0.08	<	1	1	0.5	ug/dL
MSE2-813-(3)-B	MSE2-216	blood	6	Soil	225	813	3	2.8	0.26		2	1	2	ug/dL
MSE2-830-(3)-B	MSE2-218	blood	6	Soil	225	830	3	2.8	0.26		1	1	1	ug/dL
MSE2-831-(3)-B	MSE2-247	blood	6	Soil	225	831	3	2.8	0.21		1	1	1	ug/dL
MSE2-833-(3)-B	MSE2-245	blood	6	Soil	225	833	3	2.8	0.22	<	1	1	0.5	ug/dL
MSE2-844-(3)-B	MSE2-235	blood	6	Soil	225	844	3	2.8	0.24	<	1	1	0.5	ug/dL
MSE2-807-(3)-B	MSE2-242	blood	7	Soil	675	807	3	8.94	0.75		5	1	5	ug/dL
MSE2-808-(3)-B	MSE2-232	blood	7	Soil	675	808	3	8.94	0.75		4	1	4	ug/dL
MSE2-810-(3)-B	MSE2-248	blood	7	Soil	675	810	3	8.94	0.73		5	1	5	ug/dL
MSE2-828-(3)-B	MSE2-233	blood	7	Soil	675	828	3	8.94	0.64		4	1	4	ug/dL
MSE2-840-(3)-B	MSE2-228	blood	7	Soil	675	840	3	8.94	0.67		3	1	3	ug/dL
MSE2-804-(5)-B	MSE2-267	blood	1	Control	0	804	5	0	0	<	1	1	0.5	ug/dL
MSE2-820-(5)-B	MSE2-288	blood	1	Control	0	820	5	0	0	<	1	1	0.5	ug/dL
MSE2-845-(5)-B	MSE2-263	blood	1	Control	0	845	5	0	0	<	1	1	0.5	ug/dL
MSE2-802-(5)-B	MSE2-279	blood	2	Lead Acetate	25	802	5	318.75	24.81	<	1	1	0.5	ug/dL
MSE2-803-(5)-B	MSE2-284	blood	2	Lead Acetate	25	803	5	318.75	24.52	<	1	1	0.5	ug/dL
MSE2-816-(5)-B	MSE2-281	blood	2	Lead Acetate	25	816	5	318.75	26.02	<	1	1	0.5	ug/dL
MSE2-826-(5)-B	MSE2-266	blood	2	Lead Acetate	25	826	5	318.75	22.21	<	1	1	0.5	ug/dL
MSE2-838-(5)-B	MSE2-285	blood	2	Lead Acetate	25	838	5	318.75	26.02	<	1	1	0.5	ug/dL
MSE2-819-(5)-B	MSE2-287	blood	3	Lead Acetate	75	819	5	1005	66.12	<	1	1	0.5	ug/dL
MSE2-832-(5)-B	MSE2-275	blood	3	Lead Acetate	75	832	5	1005	74.17	<	1	1	0.5	ug/dL
MSE2-834-(5)-B	MSE2-289	blood	3	Lead Acetate	75	834	5	1005	82.04		1	1	1	ug/dL
MSE2-839-(5)-B	MSE2-271	blood	3	Lead Acetate	75	839	5	1005	67.91		1	1	1	ug/dL
MSE2-846-(5)-B	MSE2-286	blood	3	Lead Acetate	75	846	5	1005	83.06		1	1	1	ug/dL
MSE2-801-(5)-B	MSE2-264	blood	4	Lead Acetate	225	801	5	2819.25	226.45		4	1	4	ug/dL
MSE2-806-(5)-B	MSE2-278	blood	4	Lead Acetate	225	806	5	2819.25	209.61		3	1	3	ug/dL
MSE2-823-(5)-B	MSE2-270	blood	4	Lead Acetate	225	823	5	2819.25	208.83		3	1	3	ug/dL
MSE2-835-(5)-B	MSE2-273	blood	4	Lead Acetate	225	835	5	2819.25	251.72		3	1	3	ug/dL
MSE2-850-(5)-B	MSE2-253	blood	4	Lead Acetate	225	850	5	0.88	0.07		7	1	7	ug/dL
MSE2-809-(5)-B	MSE2-269	blood	5	Soil	75	809	5	0.88	0.07	<	1	1	0.5	ug/dL
MSE2-812-(5)-B	MSE2-274	blood	5	Soil	75	812	5	2819.25	257.47		1	1	1	ug/dL
MSE2-817-(5)-B	MSE2-255	blood	5	Soil	75	817	5	0.88	0.08	<	1	1	0.5	ug/dL
MSE2-824-(5)-B	MSE2-259	blood	5	Soil	75	824	5	0.88	0.07	<	1	1	0.5	ug/dL
MSE2-825-(5)-B	MSE2-283	blood	5	Soil	75	825	5	0.88	0.07	<	1	1	0.5	ug/dL

TABLE A-5

Sample Number	Tag Number	Matrix	Group	Material Administered	Target Dose (ug/kg-d)	Pig Number	Collection Day	Actual Dose (ug/d)	Actual BWAdj Dose (ug/d)	Q	Pb Conc	DL	AdjConc	Units
MSE2-813-(5)-B	MSE2-256	blood	6	Soil	225	813	5	2.8	0.24		1	1	1	ug/dL
MSE2-830-(5)-B	MSE2-265	blood	6	Soil	225	830	5	2.8	0.24		3	1	3	ug/dL
MSE2-831-(5)-B	MSE2-260	blood	6	Soil	225	831	5	2.8	0.2		3	1	3	ug/dL
MSE2-833-(5)-B	MSE2-290	blood	6	Soil	225	833	5	2.8	0.2		3	1	3	ug/dL
MSE2-844-(5)-B	MSE2-268	blood	6	Soil	225	844	5	2.8	0.22		2	1	2	ug/dL
MSE2-807-(5)-B	MSE2-272	blood	7	Soil	675	807	5	8.94	0.71		5	1	5	ug/dL
MSE2-808-(5)-B	MSE2-262	blood	7	Soil	675	808	5	8.94	0.72		6	1	6	ug/dL
MSE2-810-(5)-B	MSE2-254	blood	7	Soil	675	810	5	8.94	0.69		7	1	7	ug/dL
MSE2-828-(5)-B	MSE2-258	blood	7	Soil	675	828	5	8.94	0.6		7	1	7	ug/dL
MSE2-840-(5)-B	MSE2-282	blood	7	Soil	675	840	5	8.94	0.61		6	1	6	ug/dL
MSE2-804-(7)-B	MSE2-294	blood	1	Control	0	804	7	0	0	<	1	1	0.5	ug/dL
MSE2-820-(7)-B	MSE2-320	blood	1	Control	0	820	7	0	0	<	1	1	0.5	ug/dL
MSE2-845-(7)-B	MSE2-304	blood	1	Control	0	845	7	0	0	<	1	1	0.5	ug/dL
MSE2-802-(7)-B	MSE2-311	blood	2	Lead Acetate	25	802	7	348.5	25.28	<	1	1	0.5	ug/dL
MSE2-803-(7)-B	MSE2-308	blood	2	Lead Acetate	25	803	7	348.5	25.63	<	1	1	0.5	ug/dL
MSE2-816-(7)-B	MSE2-306	blood	2	Lead Acetate	25	816	7	348.5	26.77	<	1	1	0.5	ug/dL
MSE2-826-(7)-B	MSE2-301	blood	2	Lead Acetate	25	826	7	348.5	22.56	<	1	1	0.5	ug/dL
MSE2-838-(7)-B	MSE2-293	blood	2	Lead Acetate	25	838	7	348.5	26.84	<	1	1	0.5	ug/dL
MSE2-819-(7)-B	MSE2-317	blood	3	Lead Acetate	75	819	7	1093.5	69.06	<	1	1	0.5	ug/dL
MSE2-832-(7)-B	MSE2-303	blood	3	Lead Acetate	75	832	7	1093.5	75.67		1	1	1	ug/dL
MSE2-834-(7)-B	MSE2-324	blood	3	Lead Acetate	75	834	7	1093.5	81.71		2	1	2	ug/dL
MSE2-839-(7)-B	MSE2-292	blood	3	Lead Acetate	75	839	7	1093.5	69.65		1	1	1	ug/dL
MSE2-846-(7)-B	MSE2-296	blood	3	Lead Acetate	75	846	7	1093.5	84.55		2	1	2	ug/dL
MSE2-801-(7)-B	MSE2-327	blood	4	Lead Acetate	225	801	7	3046.5	225.95		3	1	3	ug/dL
MSE2-806-(7)-B	MSE2-310	blood	4	Lead Acetate	225	806	7	3046.5	213.79		3	1	3	ug/dL
MSE2-823-(7)-B	MSE2-322	blood	4	Lead Acetate	225	823	7	3046.5	213.54		5	1	5	ug/dL
MSE2-835-(7)-B	MSE2-309	blood	4	Lead Acetate	225	835	7	3046.5	245.03		3	1	3	ug/dL
MSE2-850-(7)-B	MSE2-300	blood	4	Lead Acetate	225	850	7	0.97	0.08		7	1	7	ug/dL
MSE2-809-(7)-B	MSE2-298	blood	5	Soil	75	809	7	0.97	0.07		1	1	1	ug/dL
MSE2-812-(7)-B	MSE2-321	blood	5	Soil	75	812	7	3046.5	263.77		1	1	1	ug/dL
MSE2-817-(7)-B	MSE2-297	blood	5	Soil	75	817	7	0.97	0.08		1	1	1	ug/dL
MSE2-824-(7)-B	MSE2-328	blood	5	Soil	75	824	7	0.97	0.08	<	1	1	0.5	ug/dL
MSE2-825-(7)-B	MSE2-316	blood	5	Soil	75	825	7	0.97	0.07	<	1	1	0.5	ug/dL
MSE2-813-(7)-B	MSE2-319	blood	6	Soil	225	813	7	3.08	0.25		2	1	2	ug/dL
MSE2-830-(7)-B	MSE2-318	blood	6	Soil	225	830	7	3.08	0.25		2	1	2	ug/dL
MSE2-831-(7)-B	MSE2-315	blood	6	Soil	225	831	7	3.08	0.2		2	1	2	ug/dL
MSE2-833-(7)-B	MSE2-323	blood	6	Soil	225	833	7	3.08	0.21		3	1	3	ug/dL
MSE2-844-(7)-B	MSE2-312	blood	6	Soil	225	844	7	3.08	0.23		2	1	2	ug/dL
MSE2-807-(7)-B	MSE2-291	blood	7	Soil	675	807	7	9.8	0.71		6	1	6	ug/dL
MSE2-808-(7)-B	MSE2-302	blood	7	Soil	675	808	7	9.8	0.73		7	1	7	ug/dL
MSE2-810-(7)-B	MSE2-325	blood	7	Soil	675	810	7	9.8	0.73		9	1	9	ug/dL
MSE2-828-(7)-B	MSE2-313	blood	7	Soil	675	828	7	9.8	0.62		7	1	7	ug/dL
MSE2-840-(7)-B	MSE2-305	blood	7	Soil	675	840	7	9.8	0.63		8	1	8	ug/dL
MSE2-804-(9)-B	MSE2-349	blood	1	Control	0	804	9	0	0	<	1	1	0.5	ug/dL
MSE2-820-(9)-B	MSE2-343	blood	1	Control	0	820	9	0	0	<	1	1	0.5	ug/dL
MSE2-845-(9)-B	MSE2-332	blood	1	Control	0	845	9	0	0	<	1	1	0.5	ug/dL
MSE2-802-(9)-B	MSE2-333	blood	2	Lead Acetate	25	802	9	379.5	25.64	<	1	1	0.5	ug/dL
MSE2-803-(9)-B	MSE2-362	blood	2	Lead Acetate	25	803	9	379.5	26.11	<	1	1	0.5	ug/dL
MSE2-816-(9)-B	MSE2-361	blood	2	Lead Acetate	25	816	9	379.5	27.27	<	1	1	0.5	ug/dL
MSE2-826-(9)-B	MSE2-356	blood	2	Lead Acetate	25	826	9	379.5	23.09	<	1	1	0.5	ug/dL
MSE2-838-(9)-B	MSE2-355	blood	2	Lead Acetate	25	838	9	379.5	27.17	<	1	1	0.5	ug/dL
MSE2-819-(9)-B	MSE2-335	blood	3	Lead Acetate	75	819	9	1192.5	71.41	<	1	1	0.5	ug/dL
MSE2-832-(9)-B	MSE2-366	blood	3	Lead Acetate	75	832	9	1192.5	77.18		1	1	1	ug/dL
MSE2-834-(9)-B	MSE2-344	blood	3	Lead Acetate	75	834	9	1192.5	82.15	<	1	1	0.5	ug/dL
MSE2-839-(9)-B	MSE2-336	blood	3	Lead Acetate	75	839	9	1192.5	71.12	<	1	1	0.5	ug/dL
MSE2-846-(9)-B	MSE2-360	blood	3	Lead Acetate	75	846	9	1192.5	85.59	<	1	1	0.5	ug/dL
MSE2-801-(9)-B	MSE2-339	blood	4	Lead Acetate	225	801	9	3350.25	230.26		3	1	3	ug/dL
MSE2-806-(9)-B	MSE2-337	blood	4	Lead Acetate	225	806	9	3350.25	219.93		3	1	3	ug/dL
MSE2-823-(9)-B	MSE2-350	blood	4	Lead Acetate	225	823	9	3350.25	220.9		3	1	3	ug/dL
MSE2-835-(9)-B	MSE2-329	blood	4	Lead Acetate	225	835	9	3350.25	235.11		3	1	3	ug/dL
MSE2-850-(9)-B	MSE2-330	blood	4	Lead Acetate	225	850	9	1.05	0.12		6	1	6	ug/dL
MSE2-809-(9)-B	MSE2-353	blood	5	Soil	75	809	9	1.05	0.07	<	1	1	0.5	ug/dL
MSE2-812-(9)-B	MSE2-340	blood	5	Soil	75	812	9	3350.25	273.49		1	1	1	ug/dL
MSE2-817-(9)-B	MSE2-348	blood	5	Soil	75	817	9	1.05	0.08	<	1	1	0.5	ug/dL
MSE2-824-(9)-B	MSE2-347	blood	5	Soil	75	824	9	1.05	0.08	<	1	1	0.5	ug/dL
MSE2-825-(9)-B	MSE2-365	blood	5	Soil	75	825	9	1.05	0.07	<	1	1	0.5	ug/dL
MSE2-813-(9)-B	MSE2-352	blood	6	Soil	225	813	9	3.39	0.25		2	1	2	ug/dL
MSE2-830-(9)-B	MSE2-345	blood	6	Soil	225	830	9	3.39	0.25		2	1	2	ug/dL
MSE2-831-(9)-B	MSE2-351	blood	6	Soil	225	831	9	3.39	0.21		1	1	1	ug/dL
MSE2-833-(9)-B	MSE2-338	blood	6	Soil	225	833	9	3.39	0.22		2	1	2	ug/dL
MSE2-844-(9)-B	MSE2-357	blood	6	Soil	225	844	9	3.39	0.24		2	1	2	ug/dL
MSE2-807-(9)-B	MSE2-364	blood	7	Soil	675	807	9	10.67	0.73		4	1	4	ug/dL
MSE2-808-(9)-B	MSE2-334	blood	7	Soil	675	808	9	10.67	0.75		6	1	6	ug/dL
MSE2-810-(9)-B	MSE2-358	blood	7	Soil	675	810	9	10.67	0.75		6	1	6	ug/dL
MSE2-828-(9)-B	MSE2-359	blood	7	Soil	675	828	9	10.67	0.64		6	1	6	ug/dL
MSE2-840-(9)-B	MSE2-354	blood	7	Soil	675	840	9	10.67	0.65		4	1	4	ug/dL
MSE2-804-(12)-B	MSE2-376	blood	1	Control	0	804	12	0	0	<	1	1	0.5	ug/dL
MSE2-820-(12)-B	MSE2-396	blood	1	Control	0	820	12	0	0	<	1	1	0.5	ug/dL
MSE2-845-(12)-B	MSE2-390	blood	1	Control	0	845	12	0	0	<	1	1	0.5	ug/dL

TABLE A-5

Sample Number	Tag Number	Matrix	Group	Material Administered	Target Dose (ug/kg-d)	Pig Number	Collection Day	Actual Dose (ug/d)	Actual BWAdj Dose (ug/d)	Q	Pb Conc	DL	AdjConc	Units
MSE2-802-(12)-B	MSE2-392	blood	2	Lead Acetate	25	802	12	420.75	25.53	<	1	1	0.5	ug/dL
MSE2-803-(12)-B	MSE2-395	blood	2	Lead Acetate	25	803	12	420.75	24.39	<	1	1	0.5	ug/dL
MSE2-816-(12)-B	MSE2-368	blood	2	Lead Acetate	25	816	12	420.75	27.2	<	1	1	0.5	ug/dL
MSE2-826-(12)-B	MSE2-388	blood	2	Lead Acetate	25	826	12	420.75	23.66	<	1	1	0.5	ug/dL
MSE2-838-(12)-B	MSE2-370	blood	2	Lead Acetate	25	838	12	420.75	26.74	<	1	1	0.5	ug/dL
MSE2-819-(12)-B	MSE2-391	blood	3	Lead Acetate	75	819	12	1321.5	72.28	<	1	1	0.5	ug/dL
MSE2-832-(12)-B	MSE2-374	blood	3	Lead Acetate	75	832	12	1321.5	77.21	<	1	1	0.5	ug/dL
MSE2-834-(12)-B	MSE2-401	blood	3	Lead Acetate	75	834	12	1321.5	81.66	<	1	1	0.5	ug/dL
MSE2-839-(12)-B	MSE2-382	blood	3	Lead Acetate	75	839	12	1321.5	71.18		1	1	1	ug/dL
MSE2-846-(12)-B	MSE2-381	blood	3	Lead Acetate	75	846	12	1321.5	84.71		1	1	1	ug/dL
MSE2-801-(12)-B	MSE2-402	blood	4	Lead Acetate	225	801	12	3875.63	239.48		4	1	4	ug/dL
MSE2-806-(12)-B	MSE2-373	blood	4	Lead Acetate	225	806	12	3875.63	222.74		5	1	5	ug/dL
MSE2-823-(12)-B	MSE2-385	blood	4	Lead Acetate	225	823	12	3875.63	232.31		3	1	3	ug/dL
MSE2-835-(12)-B	MSE2-383	blood	4	Lead Acetate	225	835	12	3875.63	224.46		3	1	3	ug/dL
MSE2-850-(12)-B	MSE2-399	blood	4	Lead Acetate	225	850	12	0	0	NA		1		ug/dL
MSE2-809-(12)-B	MSE2-387	blood	5	Soil	75	809	12	1.15	0.08	<	1	1	0.5	ug/dL
MSE2-812-(12)-B	MSE2-384	blood	5	Soil	75	812	12	3875.63	286.02		2	1	2	ug/dL
MSE2-817-(12)-B	MSE2-369	blood	5	Soil	75	817	12	1.15	0.08		1	1	1	ug/dL
MSE2-824-(12)-B	MSE2-393	blood	5	Soil	75	824	12	1.15	0.08		2	1	2	ug/dL
MSE2-825-(12)-B	MSE2-375	blood	5	Soil	75	825	12	1.15	0.07	<	1	1	0.5	ug/dL
MSE2-813-(12)-B	MSE2-378	blood	6	Soil	225	813	12	3.72	0.25		2	1	2	ug/dL
MSE2-830-(12)-B	MSE2-404	blood	6	Soil	225	830	12	3.72	0.25		2	1	2	ug/dL
MSE2-831-(12)-B	MSE2-394	blood	6	Soil	225	831	12	3.72	0.21		2	1	2	ug/dL
MSE2-833-(12)-B	MSE2-386	blood	6	Soil	225	833	12	3.72	0.22		2	1	2	ug/dL
MSE2-844-(12)-B	MSE2-389	blood	6	Soil	225	844	12	3.72	0.24		3	1	3	ug/dL
MSE2-807-(12)-B	MSE2-379	blood	7	Soil	675	807	12	11.64	0.74		4	1	4	ug/dL
MSE2-808-(12)-B	MSE2-380	blood	7	Soil	675	808	12	11.64	0.75		7	1	7	ug/dL
MSE2-810-(12)-B	MSE2-377	blood	7	Soil	675	810	12	11.64	0.73		6	1	6	ug/dL
MSE2-828-(12)-B	MSE2-372	blood	7	Soil	675	828	12	11.64	0.62		3	1	3	ug/dL
MSE2-840-(12)-B	MSE2-403	blood	7	Soil	675	840	12	11.64	0.65		7	1	7	ug/dL
MSE2-804-(15)-B	MSE2-436	blood	1	Control	0	804	15			<	1	1	0.5	ug/dL
MSE2-820-(15)-B	MSE2-435	blood	1	Control	0	820	15			<	1	1	0.5	ug/dL
MSE2-845-(15)-B	MSE2-422	blood	1	Control	0	845	15			<	1	1	0.5	ug/dL
MSE2-802-(15)-B	MSE2-442	blood	2	Lead Acetate	25	802	15			<	1	1	0.5	ug/dL
MSE2-803-(15)-B	MSE2-407	blood	2	Lead Acetate	25	803	15			<	1	1	0.5	ug/dL
MSE2-816-(15)-B	MSE2-428	blood	2	Lead Acetate	25	816	15			<	1	1	0.5	ug/dL
MSE2-826-(15)-B	MSE2-424	blood	2	Lead Acetate	25	826	15			<	1	1	0.5	ug/dL
MSE2-838-(15)-B	MSE2-419	blood	2	Lead Acetate	25	838	15			<	1	1	0.5	ug/dL
MSE2-819-(15)-B	MSE2-405	blood	3	Lead Acetate	75	819	15			<	1	1	0.5	ug/dL
MSE2-832-(15)-B	MSE2-438	blood	3	Lead Acetate	75	832	15			<	1	1	0.5	ug/dL
MSE2-834-(15)-B	MSE2-406	blood	3	Lead Acetate	75	834	15			<	1	1	0.5	ug/dL
MSE2-839-(15)-B	MSE2-412	blood	3	Lead Acetate	75	839	15				1	1	1	ug/dL
MSE2-846-(15)-B	MSE2-416	blood	3	Lead Acetate	75	846	15				2	1	2	ug/dL
MSE2-801-(15)-B	MSE2-432	blood	4	Lead Acetate	225	801	15				5	1	5	ug/dL
MSE2-806-(15)-B	MSE2-434	blood	4	Lead Acetate	225	806	15				5	1	5	ug/dL
MSE2-823-(15)-B	MSE2-440	blood	4	Lead Acetate	225	823	15				2	1	2	ug/dL
MSE2-835-(15)-B	MSE2-417	blood	4	Lead Acetate	225	835	15				1	1	1	ug/dL
MSE2-850-(15)-B	MSE2-421	blood	4	Lead Acetate	225	850	15			NA		1		ug/dL
MSE2-809-(15)-B	MSE2-423	blood	5	Soil	75	809	15			<	1	1	0.5	ug/dL
MSE2-812-(15)-B	MSE2-411	blood	5	Soil	75	812	15				2	1	2	ug/dL
MSE2-817-(15)-B	MSE2-437	blood	5	Soil	75	817	15				1	1	1	ug/dL
MSE2-824-(15)-B	MSE2-429	blood	5	Soil	75	824	15				2	1	2	ug/dL
MSE2-825-(15)-B	MSE2-415	blood	5	Soil	75	825	15			<	1	1	0.5	ug/dL
MSE2-813-(15)-B	MSE2-425	blood	6	Soil	225	813	15				3	1	3	ug/dL
MSE2-830-(15)-B	MSE2-408	blood	6	Soil	225	830	15				3	1	3	ug/dL
MSE2-831-(15)-B	MSE2-439	blood	6	Soil	225	831	15				3	1	3	ug/dL
MSE2-833-(15)-B	MSE2-431	blood	6	Soil	225	833	15				3	1	3	ug/dL
MSE2-844-(15)-B	MSE2-433	blood	6	Soil	225	844	15			<	1	1	0.5	ug/dL
MSE2-807-(15)-B	MSE2-414	blood	7	Soil	675	807	15				6	1	6	ug/dL
MSE2-808-(15)-B	MSE2-426	blood	7	Soil	675	808	15				7	1	7	ug/dL
MSE2-810-(15)-B	MSE2-418	blood	7	Soil	675	810	15				11	1	11	ug/dL
MSE2-828-(15)-B	MSE2-441	blood	7	Soil	675	828	15				5	1	5	ug/dL
MSE2-840-(15)-B	MSE2-410	blood	7	Soil	675	840	15				5	1	5	ug/dL
MSE2-804-(15)-F	MSE2-546	femur	1	Control	0	804	15				0.6	0.5	0.6	ng/mg
MSE2-820-(15)-F	MSE2-540	femur	1	Control	0	820	15			<	0.5	0.5	0.3	ng/mg
MSE2-845-(15)-F	MSE2-545	femur	1	Control	0	845	15				0.7	0.5	0.7	ng/mg
MSE2-802-(15)-F	MSE2-515	femur	2	Lead Acetate	25	802	15				2.5	0.5	2.5	ng/mg
MSE2-803-(15)-F	MSE2-529	femur	2	Lead Acetate	25	803	15				2.4	0.5	2.4	ng/mg
MSE2-816-(15)-F	MSE2-547	femur	2	Lead Acetate	25	816	15				1.6	0.5	1.6	ng/mg
MSE2-826-(15)-F	MSE2-522	femur	2	Lead Acetate	25	826	15				2	0.5	2	ng/mg
MSE2-838-(15)-F	MSE2-528	femur	2	Lead Acetate	25	838	15				2.3	0.5	2.3	ng/mg
MSE2-819-(15)-F	MSE2-532	femur	3	Lead Acetate	75	819	15				4	0.5	4	ng/mg
MSE2-832-(15)-F	MSE2-519	femur	3	Lead Acetate	75	832	15				5.1	0.5	5.1	ng/mg
MSE2-834-(15)-F	MSE2-534	femur	3	Lead Acetate	75	834	15				2.5	0.5	2.5	ng/mg
MSE2-839-(15)-F	MSE2-521	femur	3	Lead Acetate	75	839	15				5.2	0.5	5.2	ng/mg
MSE2-846-(15)-F	MSE2-539	femur	3	Lead Acetate	75	846	15				3.7	0.5	3.7	ng/mg
MSE2-801-(15)-F	MSE2-526	femur	4	Lead Acetate	225	801	15				12.3	0.5	12.3	ng/mg
MSE2-806-(15)-F	MSE2-543	femur	4	Lead Acetate	225	806	15				13.6	0.5	13.6	ng/mg
MSE2-823-(15)-F	MSE2-516	femur	4	Lead Acetate	225	823	15				10.6	0.5	10.6	ng/mg

TABLE A-5

Sample Number	Tag Number	Matrix	Group	Material Administered	Target Dose (ug/kg-d)	Pig Number	Collection Day	Actual Dose (ug/d)	Actual BWAdj Dose (ug/d)	Q	Pb Conc	DL	AdjConc	Units
MSE2-835-(15)-F	MSE2-518	femur	4	Lead Acetate	225	835	15				15.1	0.5	15.1	ng/mg
MSE2-850-(15)-F	MSE2-520	femur	4	Lead Acetate	225	850	15			NA		0.5		ng/mg
MSE2-809-(15)-F	MSE2-537	femur	5	Soil	75	809	15				2.9	0.5	2.9	ng/mg
MSE2-812-(15)-F	MSE2-542	femur	5	Soil	75	812	15				3.5	0.5	3.5	ng/mg
MSE2-817-(15)-F	MSE2-531	femur	5	Soil	75	817	15				3.1	0.5	3.1	ng/mg
MSE2-824-(15)-F	MSE2-523	femur	5	Soil	75	824	15				4.1	0.5	4.1	ng/mg
MSE2-825-(15)-F	MSE2-550	femur	5	Soil	75	825	15				3.1	0.5	3.1	ng/mg
MSE2-813-(15)-F	MSE2-548	femur	6	Soil	225	813	15				9.7	0.5	9.7	ng/mg
MSE2-830-(15)-F	MSE2-536	femur	6	Soil	225	830	15				9.2	0.5	9.2	ng/mg
MSE2-831-(15)-F	MSE2-533	femur	6	Soil	225	831	15				7.6	0.5	7.6	ng/mg
MSE2-833-(15)-F	MSE2-549	femur	6	Soil	225	833	15				8.6	0.5	8.6	ng/mg
MSE2-844-(15)-F	MSE2-527	femur	6	Soil	225	844	15				8.6	0.5	8.6	ng/mg
MSE2-807-(15)-F	MSE2-538	femur	7	Soil	675	807	15				22.2	0.5	22.2	ng/mg
MSE2-808-(15)-F	MSE2-544	femur	7	Soil	675	808	15				28.7	1	28.7	ng/mg
MSE2-810-(15)-F	MSE2-535	femur	7	Soil	675	810	15				27.4	1	27.4	ng/mg
MSE2-828-(15)-F	MSE2-517	femur	7	Soil	675	828	15				24	0.5	24	ng/mg
MSE2-840-(15)-F	MSE2-524	femur	7	Soil	675	840	15				25.7	0.5	25.7	ng/mg
MSE2-804-(15)-K	MSE2-498	kidney	1	Control	0	804	15			<	10	10	5	ng/g
MSE2-820-(15)-K	MSE2-487	kidney	1	Control	0	820	15			<	20	20	10	ng/g
MSE2-845-(15)-K	MSE2-479	kidney	1	Control	0	845	15			<	10	10	5	ng/g
MSE2-802-(15)-K	MSE2-488	kidney	2	Lead Acetate	25	802	15				30	10	30	ng/g
MSE2-803-(15)-K	MSE2-508	kidney	2	Lead Acetate	25	803	15				50	10	50	ng/g
MSE2-816-(15)-K	MSE2-505	kidney	2	Lead Acetate	25	816	15				20	10	20	ng/g
MSE2-826-(15)-K	MSE2-483	kidney	2	Lead Acetate	25	826	15				30	10	30	ng/g
MSE2-838-(15)-K	MSE2-510	kidney	2	Lead Acetate	25	838	15				20	10	20	ng/g
MSE2-819-(15)-K	MSE2-501	kidney	3	Lead Acetate	75	819	15				100	10	100	ng/g
MSE2-832-(15)-K	MSE2-485	kidney	3	Lead Acetate	75	832	15				80	10	80	ng/g
MSE2-834-(15)-K	MSE2-502	kidney	3	Lead Acetate	75	834	15				70	10	70	ng/g
MSE2-839-(15)-K	MSE2-500	kidney	3	Lead Acetate	75	839	15				90	10	90	ng/g
MSE2-846-(15)-K	MSE2-513	kidney	3	Lead Acetate	75	846	15				70	10	70	ng/g
MSE2-801-(15)-K	MSE2-495	kidney	4	Lead Acetate	225	801	15				300	10	300	ng/g
MSE2-806-(15)-K	MSE2-503	kidney	4	Lead Acetate	225	806	15				360	10	360	ng/g
MSE2-823-(15)-K	MSE2-504	kidney	4	Lead Acetate	225	823	15				220	10	220	ng/g
MSE2-835-(15)-K	MSE2-480	kidney	4	Lead Acetate	225	835	15				180	10	180	ng/g
MSE2-850-(15)-K	MSE2-486	kidney	4	Lead Acetate	225	850	15			NA		10		ng/g
MSE2-809-(15)-K	MSE2-489	kidney	5	Soil	75	809	15				40	10	40	ng/g
MSE2-812-(15)-K	MSE2-493	kidney	5	Soil	75	812	15				90	10	90	ng/g
MSE2-817-(15)-K	MSE2-509	kidney	5	Soil	75	817	15				60	10	60	ng/g
MSE2-824-(15)-K	MSE2-512	kidney	5	Soil	75	824	15				80	10	80	ng/g
MSE2-825-(15)-K	MSE2-496	kidney	5	Soil	75	825	15				70	10	70	ng/g
MSE2-813-(15)-K	MSE2-511	kidney	6	Soil	225	813	15				230	10	230	ng/g
MSE2-830-(15)-K	MSE2-482	kidney	6	Soil	225	830	15				190	10	190	ng/g
MSE2-831-(15)-K	MSE2-514	kidney	6	Soil	225	831	15				160	10	160	ng/g
MSE2-833-(15)-K	MSE2-494	kidney	6	Soil	225	833	15				180	10	180	ng/g
MSE2-844-(15)-K	MSE2-481	kidney	6	Soil	225	844	15				160	10	160	ng/g
MSE2-807-(15)-K	MSE2-491	kidney	7	Soil	675	807	15				600	20	600	ng/g
MSE2-808-(15)-K	MSE2-506	kidney	7	Soil	675	808	15				700	20	700	ng/g
MSE2-810-(15)-K	MSE2-484	kidney	7	Soil	675	810	15				1030	20	1030	ng/g
MSE2-828-(15)-K	MSE2-499	kidney	7	Soil	675	828	15				530	20	530	ng/g
MSE2-840-(15)-K	MSE2-497	kidney	7	Soil	675	840	15				570	20	570	ng/g
MSE2-804-(15)-L	MSE2-477	liver	1	Control	0	804	15			<	10	10	5	ng/g
MSE2-820-(15)-L	MSE2-456	liver	1	Control	0	820	15			<	10	10	5	ng/g
MSE2-845-(15)-L	MSE2-446	liver	1	Control	0	845	15			<	10	10	5	ng/g
MSE2-802-(15)-L	MSE2-466	liver	2	Lead Acetate	25	802	15				30	10	30	ng/g
MSE2-803-(15)-L	MSE2-471	liver	2	Lead Acetate	25	803	15				30	10	30	ng/g
MSE2-816-(15)-L	MSE2-461	liver	2	Lead Acetate	25	816	15				10	10	10	ng/g
MSE2-826-(15)-L	MSE2-453	liver	2	Lead Acetate	25	826	15				20	10	20	ng/g
MSE2-838-(15)-L	MSE2-473	liver	2	Lead Acetate	25	838	15				30	10	30	ng/g
MSE2-819-(15)-L	MSE2-470	liver	3	Lead Acetate	75	819	15				60	10	60	ng/g
MSE2-832-(15)-L	MSE2-467	liver	3	Lead Acetate	75	832	15				60	10	60	ng/g
MSE2-834-(15)-L	MSE2-457	liver	3	Lead Acetate	75	834	15				60	10	60	ng/g
MSE2-839-(15)-L	MSE2-448	liver	3	Lead Acetate	75	839	15				90	10	90	ng/g
MSE2-846-(15)-L	MSE2-472	liver	3	Lead Acetate	75	846	15				70	10	70	ng/g
MSE2-801-(15)-L	MSE2-465	liver	4	Lead Acetate	225	801	15				310	10	310	ng/g
MSE2-806-(15)-L	MSE2-455	liver	4	Lead Acetate	225	806	15				540	20	540	ng/g
MSE2-823-(15)-L	MSE2-451	liver	4	Lead Acetate	225	823	15				340	10	340	ng/g
MSE2-835-(15)-L	MSE2-450	liver	4	Lead Acetate	225	835	15				220	10	220	ng/g
MSE2-850-(15)-L	MSE2-443	liver	4	Lead Acetate	225	850	15			NA		10		ng/g
MSE2-809-(15)-L	MSE2-474	liver	5	Soil	75	809	15				60	10	60	ng/g
MSE2-812-(15)-L	MSE2-444	liver	5	Soil	75	812	15				90	10	90	ng/g
MSE2-817-(15)-L	MSE2-464	liver	5	Soil	75	817	15				50	10	50	ng/g
MSE2-824-(15)-L	MSE2-462	liver	5	Soil	75	824	15				50	10	50	ng/g
MSE2-825-(15)-L	MSE2-447	liver	5	Soil	75	825	15				90	10	90	ng/g
MSE2-813-(15)-L	MSE2-452	liver	6	Soil	225	813	15				180	10	180	ng/g
MSE2-830-(15)-L	MSE2-469	liver	6	Soil	225	830	15				110	10	110	ng/g
MSE2-831-(15)-L	MSE2-459	liver	6	Soil	225	831	15				180	10	180	ng/g
MSE2-833-(15)-L	MSE2-478	liver	6	Soil	225	833	15				220	10	220	ng/g
MSE2-844-(15)-L	MSE2-460	liver	6	Soil	225	844	15				220	10	220	ng/g
MSE2-807-(15)-L	MSE2-445	liver	7	Soil	675	807	15				930	20	930	ng/g

TABLE A-5

Sample Number	Tag Number	Matrix	Group	Material Administered	Target Dose (ug/kg-d)	Pig Number	Collection Day	Actual Dose (ug/d)	Actual BWAdj Dose (ug/d)	Q	Pb Conc	DL	AdjConc	Units
MSE2-808-(15)-L	MSE2-463	liver	7	Soil	675	808	15				1450	50	1450	ng/g
MSE2-810-(15)-L	MSE2-458	liver	7	Soil	675	810	15				1750	50	1750	ng/g
MSE2-828-(15)-L	MSE2-454	liver	7	Soil	675	828	15				460	10	460	ng/g
MSE2-840-(15)-L	MSE2-476	liver	7	Soil	675	840	15				920	50	920	ng/g

Actual Dose and Actual BW Adj Dose: Values presented are for individual dosing days only; average doses over the course of the study are presented in Table A-3, as well as Table 2-1 in the main text.
Pb Conc: Acounts for all dilutions in sample preparation and analysis.
AdjConc: Non-detects evaluated at 1/2 the quantitation limit (DL).

TABLE A-6

LEAD ANALYTICAL RESULTS FOR QUALITY CONTROL SAMPLES

Analytical Spikes

Sample Number	Matrix	Analyte	Nominal Spike (ug/L)	Conc (spiked sample) ug/L	Original Conc (ug/L)	Percent Recovery
MSE2-122	blood	Pb	4	3.68	<DL	92%
MSE2-142	blood	Pb	4	4.73	<DL	118%
MSE2-164	blood	Pb	4	5.48	2.15	83%
MSE2-185	blood	Pb	4	3.55	<DL	89%
MSE2-196	blood	Pb	4	6.01	2.25	94%
MSE2-207	blood	Pb	4	11	7.49	88%
MSE2-225	blood	Pb	4	5.35	0.94	110%
MSE2-236	blood	Pb	4	4.25	<DL	106%
MSE2-247	blood	Pb	4	5.18	1.08	103%
MSE2-258	blood	Pb	4	11.1	7.11	100%
MSE2-269	blood	Pb	4	4.5	<DL	113%
MSE2-280	blood	Pb	4	3.87	<DL	97%
MSE2-290	blood	Pb	4	6.86	2.81	102%
MSE2-301	blood	Pb	4	3.96	<DL	99%
MSE2-312	blood	Pb	4	6.22	1.98	106%
MSE2-323	blood	Pb	4	6.99	2.99	99%
MSE2-339	blood	Pb	4	7.03	3.38	91%
MSE2-350	blood	Pb	4	6.89	2.95	99%
MSE2-361	blood	Pb	4	3.65	<DL	91%
MSE2-372	blood	Pb	4	7.08	3.34	94%
MSE2-382	blood	Pb	4	5.08	1.08	99%
MSE2-393	blood	Pb	4	5.65	1.68	99%
MSE2-405	blood	Pb	4	5.04	0.78	107%
MSE2-416	blood	Pb	4	5.43	1.53	98%
MSE2-428	blood	Pb	4	3.62	<DL	90%
MSE2-439	blood	Pb	4	7.44	3.25	105%
MSE2-449	liver	Pb	20	24.5	3.71	104%
MSE2-458	liver	Pb	20	56	34.9	106%
MSE2-469	liver	Pb	20	31.2	11.1	101%
MSE2-497	kidney	Pb	20	45.6	28.4	86%
MSE2-506	kidney	Pb	20	56.3	34.8	108%
MSE2-515	femur	Pb	20	24.1	4.97	96%
MSE2-534	femur	Pb	20	22.6	5.03	88%
MSE2-543	femur	Pb	20	42.6	23.7	95%

Analytical Duplicates (Post-Digestion)

Sample Number	Matrix	Analyte	Conc (duplicate) ug/L	Original Conc (ug/L)	Absolute Difference or RPD
MSE2-105	blood	Pb	<DL	<DL	NA
MSE2-115	blood	Pb	<DL	<DL	NA
MSE2-125	blood	Pb	<DL	<DL	NA
MSE2-135	blood	Pb	<DL	<DL	NA
MSE2-145	blood	Pb	1	1	within 1
MSE2-155	blood	Pb	6	6	within 1
MSE2-165	blood	Pb	3	3	within 1
MSE2-175	blood	Pb	<DL	<DL	NA
MSE2-185	blood	Pb	<DL	<DL	NA
MSE2-195	blood	Pb	1	1	within 1
MSE2-205	blood	Pb	<DL	<DL	NA
MSE2-220	blood	Pb	<DL	<DL	NA
MSE2-230	blood	Pb	1	1	within 1
MSE2-240	blood	Pb	<DL	<DL	NA
MSE2-250	blood	Pb	<DL	<DL	NA
MSE2-260	blood	Pb	3	3	within 1
MSE2-270	blood	Pb	3	3	within 1
MSE2-280	blood	Pb	<DL	<DL	NA
MSE2-290	blood	Pb	3	3	within 1
MSE2-300	blood	Pb	7	7	within 1
MSE2-310	blood	Pb	3	3	within 1
MSE2-320	blood	Pb	<DL	<DL	NA
MSE2-332	blood	Pb	<DL	<DL	NA
MSE2-342	blood	Pb	5	5	within 1
MSE2-352	blood	Pb	2	2	within 1
MSE2-362	blood	Pb	<DL	<DL	NA
MSE2-372	blood	Pb	3	3	within 1
MSE2-382	blood	Pb	1	1	within 1
MSE2-392	blood	Pb	<DL	<DL	NA
MSE2-404	blood	Pb	2	2	within 1
MSE2-414	blood	Pb	6	6	within 1
MSE2-425	blood	Pb	2	3	within 1
MSE2-435	blood	Pb	<DL	<DL	NA
MSE2-453	liver	Pb	1.92	1.74	within 1
MSE2-465	liver	Pb	31.1	31.8	2.0%
MSE2-475	liver	Pb	5.46	6.14	within 1
MSE2-485	kidney	Pb	7.7	7.73	within 1
MSE2-496	kidney	Pb	7.35	5.95	within 1
MSE2-504	kidney	Pb	22	23.9	8.5%
MSE2-514	kidney	Pb	15.6	16.8	7.4%
MSE2-523	femur	Pb	4.1	3.9	within 1
MSE2-533	femur	Pb	7.6	8	within 1
MSE2-543	femur	Pb	13.6	11.8	14.2%
MSE2-550	femur	Pb	3.1	3.7	within 1

Laboratory Control Standards

QC Std ID	QC Std Conc	Analyte	Unadjusted Concentration	Percent Recovery
DOLT-3	0.319 µg/g	Pb	0.27 µg/g	84.6%
DOLT-3	0.319 µg/g	Pb	0.24 µg/g	75.2%
TORT-2	0.35 µg/g	Pb	0.27 µg/g	77.1%
TORT-2	0.35 µg/g	Pb	0.243 µg/g	68.6%
NIST 1400	9.07 µg/g	Pb	9.09 µg/g	100.2%
LUTS-1	0.01 µg/g	Pb	< DL (0.01) µg/g	--
ERA 697 1/5	17.5 µg/L	Pb	18.5 µg/L	106.0%
ERA 697 1/5	17.5 µg/L	Pb	18.5 µg/L	105.7%
ERA 697 1/5	17.5 µg/L	Pb	18.8 µg/L	107.6%
ERA 697 1/5	17.5 µg/L	Pb	18.7 µg/L	107.1%
ERA 697 1/5	17.5 µg/L	Pb	19.1 µg/L	109.0%
ERA 697 1/5	17.5 µg/L	Pb	16.3 µg/L	93.0%
ERA 697 1/5	17.5 µg/L	Pb	19.2 µg/L	109.9%
ERA 697 1/5	17.5 µg/L	Pb	18.1 µg/L	103.2%
ERA 697 1/5	17.5 µg/L	Pb	18.3 µg/L	104.8%
ERA 697 1/5	17.5 µg/L	Pb	18.4 µg/L	105.1%
ERA 697 1/5	17.5 µg/L	Pb	19 µg/L	108.5%
ERA 697 1/5	17.5 µg/L	Pb	17.5 µg/L	100.3%
ERA 697 1/5	17.5 µg/L	Pb	17.5 µg/L	99.8%
ERA 697 1/5	17.5 µg/L	Pb	18.9 µg/L	108.2%
ERA 697 1/5	17.5 µg/L	Pb	17.5 µg/L	100.2%
ERA 697 1/5	17.5 µg/L	Pb	16.5 µg/L	94.5%
ERA 697 1/5	17.5 µg/L	Pb	19.1 µg/L	108.9%
ERA 697 1/10	8.75 µg/L	Pb	8.66 µg/L	99.0%
ERA 697 1/10	8.75 µg/L	Pb	8.77 µg/L	100.2%
ERA 697 1/10	8.75 µg/L	Pb	8.21 µg/L	93.8%
ERA 697 1/10	8.75 µg/L	Pb	8.84 µg/L	101.0%
ERA 697 1/10	8.75 µg/L	Pb	9.4 µg/L	107.4%
ERA 697 1/10	8.75 µg/L	Pb	9.5 µg/L	108.6%
ERA 697 1/10	8.75 µg/L	Pb	8.92 µg/L	101.9%
ERA 697 1/10	8.75 µg/L	Pb	8.61 µg/L	98.4%
ERA 697 1/10	8.75 µg/L	Pb	8.86 µg/L	101.5%
ERA 697 1/10	8.75 µg/L	Pb	9.2 µg/L	105.1%
ERA 697 1/10	8.75 µg/L	Pb	9.24 µg/L	105.6%
ERA 697 1/10	8.75 µg/L	Pb	9.3 µg/L	106.3%
ERA 697 1/10	8.75 µg/L	Pb	8.83 µg/L	100.9%
ERA 697 1/10	8.75 µg/L	Pb	9.04 µg/L	103.3%
ERA 697 1/10	8.75 µg/L	Pb	8.99 µg/L	102.7%
ERA 697 1/10	8.75 µg/L	Pb	9.39 µg/L	107.3%
ERA 697 1/10	8.75 µg/L	Pb	8.93 µg/L	102.1%
ERA 697 1/10	8.75 µg/L	Pb	9.1 µg/L	104.0%
ERA 697 1/10	8.75 µg/L	Pb	8.89 µg/L	101.6%
ERA 697 1/10	8.75 µg/L	Pb	9.18 µg/L	104.9%
ERA 697 1/10	8.75 µg/L	Pb	8.82 µg/L	100.8%
ERA 697 1/10	8.75 µg/L	Pb	9.05 µg/L	103.4%
ERA 697 1/10	8.75 µg/L	Pb	9.21 µg/L	105.3%
ERA 697 1/10	8.75 µg/L	Pb	9.03 µg/L	103.2%
ERA 697 1/10	8.75 µg/L	Pb	9.01 µg/L	103.0%
ERA 697 1/10	8.75 µg/L	Pb	9.35 µg/L	106.9%
ERA 697 1/10	8.75 µg/L	Pb	9.56 µg/L	109.3%
ERA 697 1/10	8.75 µg/L	Pb	9.06 µg/L	103.5%
ERA 697 1/10	8.75 µg/L	Pb	8.58 µg/L	98.1%
ERA 697 1/10	8.75 µg/L	Pb	9.39 µg/L	107.3%
ERA 697 1/10	8.75 µg/L	Pb	9.04 µg/L	103.3%
ERA 697 1/10	8.75 µg/L	Pb	9.06 µg/L	103.5%
ERA 697 1/10	8.75 µg/L	Pb	8.23 µg/L	94.1%
ERA 697 1/10	8.75 µg/L	Pb	8.6 µg/L	98.3%
ERA 697 1/10	8.75 µg/L	Pb	8.69 µg/L	99.3%
ERA 697 1/10	8.75 µg/L	Pb	8.9 µg/L	101.7%
ERA 697 1/10	8.75 µg/L	Pb	8.79 µg/L	100.5%
ERA 697 1/10	8.75 µg/L	Pb	9.04 µg/L	103.3%
ERA 697 1/10	8.75 µg/L	Pb	8.87 µg/L	101.4%
ERA 697 1/10	8.75 µg/L	Pb	8.95 µg/L	102.3%
ERA 697 1/10	8.75 µg/L	Pb	9.23 µg/L	105.5%
ERA 697 1/10	8.75 µg/L	Pb	9.16 µg/L	104.7%
ERA 697 1/10	8.75 µg/L	Pb	8.96 µg/L	102.4%

TABLE A-6

Sample Preparation Replicates

Tag Number	Matrix	QC Identifier	Original Pig #	Group	Material Administered	Target Dose (ug/kg-d)	Collection Day	Analyte	Q	DL	Pb Conc	AdjConc	Original AdjConc
MSE2-138	blood	2819	819	3	Lead Acetate	75	0	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-116	blood	2801	801	4	Lead Acetate	225	0	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-137	blood	2807	807	7	Soil	675	0	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-141	blood	2813	813	6	Soil	225	1	Pb		1	1	1 ug/dL	2
MSE2-159	blood	2802	802	2	Lead Acetate	25	1	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-162	blood	2809	809	5	Soil	75	1	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-212	blood	2804	804	1	Control	0	2	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-198	blood	2808	808	7	Soil	675	2	Pb		1	9	9 ug/dL	7
MSE2-189	blood	2832	832	3	Lead Acetate	75	2	Pb		1	2	2 ug/dL	1
MSE2-249	blood	2810	810	7	Soil	675	3	Pb		1	5	5 ug/dL	5
MSE2-217	blood	2806	806	4	Lead Acetate	225	3	Pb		1	1	1 ug/dL	2
MSE2-230	blood	2812	812	5	Soil	75	3	Pb		1	1	1 ug/dL	0.5
MSE2-257	blood	2830	830	6	Soil	225	5	Pb		1	4	4 ug/dL	3
MSE2-280	blood	2803	803	2	Lead Acetate	25	5	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-261	blood	2834	834	3	Lead Acetate	75	5	Pb		1	2	2 ug/dL	1
MSE2-307	blood	2817	817	5	Soil	75	7	Pb	<	1	1	0.5 ug/dL	1
MSE2-299	blood	2823	823	4	Lead Acetate	225	7	Pb		1	6	6 ug/dL	5
MSE2-314	blood	2831	831	6	Soil	225	7	Pb		1	2	2 ug/dL	2
MSE2-346	blood	2820	820	1	Control	0	9	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-363	blood	2816	816	2	Lead Acetate	25	9	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-342	blood	2828	828	7	Soil	675	9	Pb		1	5	5 ug/dL	6
MSE2-371	blood	2839	839	3	Lead Acetate	75	12	Pb	<	1	1	0.5 ug/dL	1
MSE2-397	blood	2824	824	5	Soil	75	12	Pb	<	1	1	0.5 ug/dL	2
MSE2-367	blood	2845	845	1	Control	0	12	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-420	blood	2835	835	4	Lead Acetate	225	15	Pb		1	4	4 ug/dL	1
MSE2-409	blood	2833	833	6	Soil	225	15	Pb	<	1	1	0.5 ug/dL	3
MSE2-430	blood	2826	826	2	Lead Acetate	25	15	Pb	<	1	1	0.5 ug/dL	0.5
MSE2-468	liver	2801	801	7	Soil	675	15	Pb		10	310	310 ng/g	310
MSE2-475	liver	2809	809	3	Lead Acetate	75	15	Pb		10	60	60 ng/g	60
MSE2-449	liver	2838	838	6	Soil	225	15	Pb		10	40	40 ng/g	30
MSE2-492	kidney	2846	846	4	Lead Acetate	225	15	Pb		10	100	100 ng/g	70
MSE2-507	kidney	2825	825	5	Soil	75	15	Pb		10	60	60 ng/g	70
MSE2-490	kidney	2838	838	2	Lead Acetate	25	15	Pb		10	30	30 ng/g	20
MSE2-530	femur	2812	812	5	Soil	75	15	Pb		0.5	4.3	4.3 ng/mg	3.5
MSE2-541	femur	2808	808	7	Soil	675	15	Pb		1	28.7	28.7 ng/mg	28.7
MSE2-525	femur	2803	803	2	Lead Acetate	25	15	Pb		0.5	2.6	2.6 ng/mg	2.4

Blood Lead Check Samples

Tag Number	Matrix	CDC Blood Lead Check Sample	CDC Concentration	Analyte	Q	Pb Conc	DL	AdjConc
MSE2-276	blood	CDC BLLRS sample 294	1.9 µg/dL	Pb	<	1	1	0.5 ug/dL
MSE2-147	blood	CDC BLLRS sample 294	1.9 µg/dL	Pb		2	1	2 ug/dL
MSE2-398	blood	CDC BLLRS sample 294	1.9 µg/dL	Pb	<	1	1	0.5 ug/dL
MSE2-341	blood	CDC BLLRS sample 294	1.9 µg/dL	Pb	<	1	1	0.5 ug/dL
MSE2-215	blood	CDC BLLRS sample 294	1.9 µg/dL	Pb	<	1	1	0.5 ug/dL
MSE2-134	blood	CDC BLLRS sample 294	1.9 µg/dL	Pb		2	1	2 ug/dL
MSE2-128	blood	CDC BLLRS sample 199	5.5 µg/dL	Pb		4	1	4 ug/dL
MSE2-193	blood	CDC BLLRS sample 199	5.5 µg/dL	Pb		4	1	4 ug/dL
MSE2-252	blood	CDC BLLRS sample 199	5.5 µg/dL	Pb		4	1	4 ug/dL
MSE2-326	blood	CDC BLLRS sample 199	5.5 µg/dL	Pb		3	1	3 ug/dL
MSE2-331	blood	CDC BLLRS sample 199	5.5 µg/dL	Pb		4	1	4 ug/dL
MSE2-427	blood	CDC BLLRS sample 199	5.5 µg/dL	Pb		4	1	4 ug/dL
MSE2-413	blood	CDC BLLRS sample 592	13.9 µg/dL	Pb		12	1	12 ug/dL
MSE2-295	blood	CDC BLLRS sample 592	13.9 µg/dL	Pb		12	1	12 ug/dL
MSE2-190	blood	CDC BLLRS sample 592	13.9 µg/dL	Pb		13	1	13 ug/dL
MSE2-172	blood	CDC BLLRS sample 592	13.9 µg/dL	Pb		12	1	12 ug/dL
MSE2-400	blood	CDC BLLRS sample 592	13.9 µg/dL	Pb		11	1	11 ug/dL
MSE2-277	blood	CDC BLLRS sample 592	13.9 µg/dL	Pb		12	1	12 ug/dL

TABLE A-7 IDENTIFICATION OF POTENTIAL BLOOD LEAD OUTLIERS

Material Administered	Group	Pig Number	Target Dose	Actual Dose*	Blood Lead (µg/dL) by Day								
					0	1	2	3	5	7	9	12	15
Control	1	804	0	0.00	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Control	1	820	0	0.00	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Control	1	845	0	0.00	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead Acetate	2	802	25	25.59	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead Acetate	2	803	25	24.26	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead Acetate	2	816	25	26.98	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead Acetate	2	826	25	23.04	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead Acetate	2	838	25	26.67	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead Acetate	3	819	75	69.40	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead Acetate	3	832	75	75.18	0.5	1.0	1.0	0.5	0.5	1.0	1.0	0.5	0.5
Lead Acetate	3	834	75	82.12	0.5	0.5	1.0	2.0	1.0	2.0	0.5	0.5	0.5
Lead Acetate	3	839	75	69.93	0.5	1.0	1.0	2.0	1.0	1.0	0.5	1.0	1.0
Lead Acetate	3	846	75	84.80	0.5	0.5	1.0	2.0	1.0	2.0	0.5	1.0	2.0
Lead Acetate	4	801	225	231.31	0.5	3.0	3.0	2.0	4.0	3.0	3.0	4.0	5.0
Lead Acetate	4	806	225	214.61	0.5	2.0	3.0	2.0	3.0	3.0	3.0	5.0	5.0
Lead Acetate	4	823	225	217.75	0.5	3.0	4.0	3.0	3.0	5.0	3.0	3.0	2.0
Lead Acetate	4	835	225	243.10	0.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.0
Lead Acetate	4	850											
Test Material 1	5	809	75	74.15	0.5	0.5	0.5	1.0	0.5	1.0	0.5	0.5	0.5
Test Material 1	5	812	75	82.33	0.5	0.5	0.5	0.5	1.0	1.0	1.0	2.0	2.0
Test Material 1	5	817	75	78.46	0.5	0.5	0.5	0.5	0.5	1.0	0.5	1.0	1.0
Test Material 1	5	824	75	76.63	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.0	2.0
Test Material 1	5	825	75	73.92	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Test Material 1	6	813	225	247.77	0.5	2.0	2.0	2.0	1.0	2.0	2.0	2.0	3.0
Test Material 1	6	830	225	250.81	0.5	0.5	2.0	1.0	3.0	2.0	2.0	2.0	3.0
Test Material 1	6	831	225	207.38	0.5	1.0	2.0	1.0	3.0	2.0	1.0	2.0	3.0
Test Material 1	6	833	225	211.21	0.5	2.0	3.0	0.5	3.0	3.0	2.0	2.0	3.0
Test Material 1	6	844	225	233.46	0.5	0.5	0.5	0.5	2.0	2.0	2.0	3.0	0.5
Test Material 1	7	807	675	722.71	0.5	6.0	6.0	5.0	5.0	6.0	4.0	4.0	6.0
Test Material 1	7	808	675	731.97	0.5	6.0	7.0	4.0	6.0	7.0	6.0	7.0	7.0
Test Material 1	7	810	675	717.80	0.5	5.0	7.0	5.0	7.0	9.0	6.0	6.0	11.0
Test Material 1	7	828	675	618.53	0.5	6.0	7.0	4.0	7.0	7.0	6.0	3.0	5.0
Test Material 1	7	840	675	638.55	0.5	8.0	8.0	3.0	6.0	8.0	4.0	7.0	5.0

*Average body weight-adjusted dose for each pig over the course of the study (days 0-14).

Note:

Data point flagged as potential outlier (group mean < 5 µg/dL)

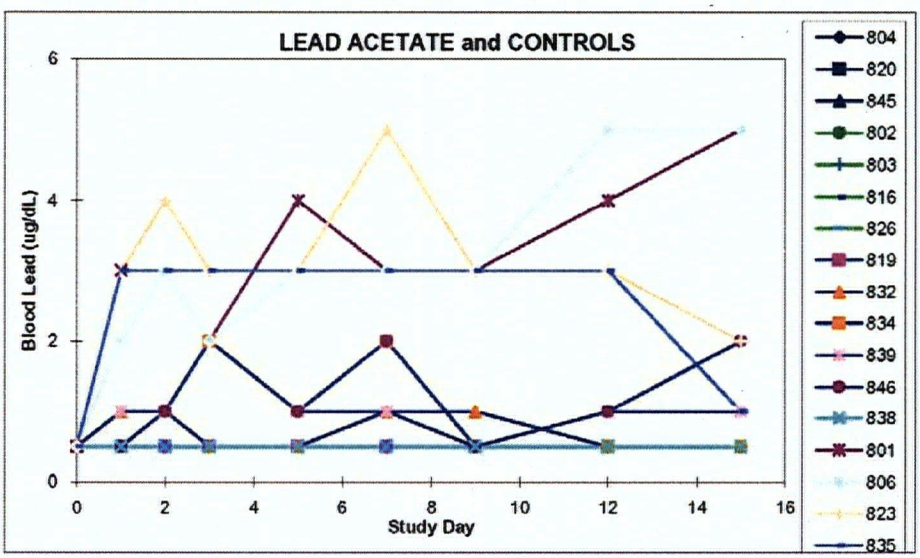
Data point flagged as potential outlier (group mean > 5 µg/dL)

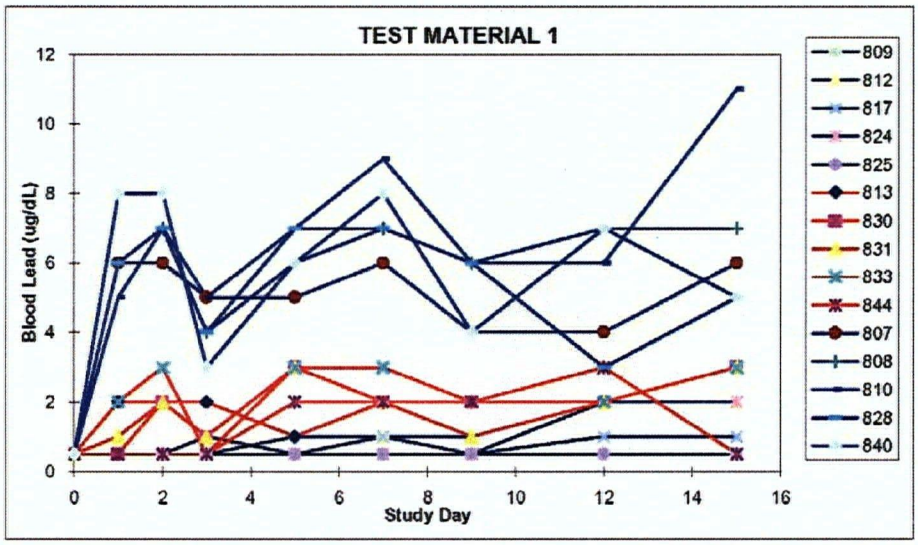
Data point judged to be outlier; excluded from further analyses

TABLE A-8 AREA UNDER CURVE DETERMINATIONS

Group	Pig Number	AUC (µg/dL-days) for Time Interval Shown								AUC Total (µg/dL-days)
		0-1	1-2	2-3	3-5	5-7	7-9	9-12	12-15	
1	804	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
1	820	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
1	845	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
2	802	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
2	803	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
2	816	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
2	826	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
2	838	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
3	819	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
3	832	0.75	1.00	0.75	1.00	1.50	2.00	2.25	1.50	10.75
3	834	0.50	0.75	1.50	3.00	3.00	2.50	1.50	1.50	14.25
3	839	0.75	1.00	1.50	3.00	2.00	1.50	2.25	3.00	15.00
3	846	0.50	0.75	1.50	3.00	3.00	2.50	2.25	4.50	18.00
4	801	1.75	3.00	2.50	6.00	7.00	6.00	10.50	13.50	50.25
4	806	1.25	2.50	2.50	5.00	6.00	6.00	12.00	15.00	50.25
4	823	1.75	3.50	3.50	6.00	8.00	8.00	9.00	7.50	47.25
4	835	1.75	3.00	3.00	6.00	6.00	6.00	9.00	6.00	40.75
4	850									
5	809	0.50	0.50	0.75	1.50	1.50	1.50	1.50	1.50	9.25
5	812	0.50	0.50	0.50	1.50	2.00	2.00	4.50	6.00	17.50
5	817	0.50	0.50	0.50	1.00	1.50	1.50	2.25	3.00	10.75
5	824	0.50	0.50	0.50	1.00	1.00	1.00	3.75	6.00	14.25
5	825	0.50	0.50	0.50	1.00	1.00	1.00	1.50	1.50	7.50
6	813	1.25	2.00	2.00	3.00	3.00	4.00	6.00	7.50	28.75
6	830	0.50	1.25	1.50	4.00	5.00	4.00	6.00	7.50	29.75
6	831	0.75	1.50	1.50	4.00	5.00	3.00	4.50	7.50	27.75
6	833	1.25	2.50	1.75	3.50	6.00	5.00	6.00	7.50	33.50
6	844	0.50	0.50	0.50	2.50	4.00	4.00	7.50	5.25	24.75
7	807	3.25	6.00	5.50	10.00	11.00	10.00	12.00	15.00	72.75
7	808	3.25	6.50	5.50	10.00	13.00	13.00	19.50	21.00	91.75
7	810	2.75	6.00	6.00	12.00	16.00	15.00	18.00	25.50	101.25
7	828	3.25	6.50	5.50	11.00	14.00	13.00	13.50	12.00	78.75
7	840	4.25	8.00	5.50	9.00	14.00	12.00	16.50	18.00	87.25

FIGURE A-1 BLOOD LEAD DATA BY DAY





APPENDIX B

Data from Drexler (2005)

TABLE 1. Laboratory of Environment and Geological Sciences, University of Colorado, Boulder

Project Name: EPA Phosphate

Run # | Date: 6/17/2005 | Operator: Drexler

Position in rack	Sample name	Lab#	Wt Grams	pH start	Starting time	Stopping time	pH stop
1	HER-2930-1	HER-2930-1	1 00021	1 544	9 47	10 47	1.569
2	HER-2930-2	HER-2930-2	1 00036	1 544	9 47	10 47	1 569
3	HER-2930-3	HER-2930-3	1 00036	1 544	9 47	10 47	1 568
4							
5							
6							
7							
8							
9							
10							

Project Name:

Run # | Date: | Operator:

Position in rack	Sample name	Lab#	Wt Grams	pH start	Starting time	Stopping time	pH stop
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

In Vitro

	As ppm	Pb ppm
HER-2930-1 all x20	-0 032	17 322
HER-2930-2	-0 027	17 062
HER-2930-3	-0 011	16 874
HER-2930-3-AD	0 019	16 755

TABLE 2. Preliminary Summary Of In Vitro Bioassay Results

Sample	ID	Pb in <250u bulk soil mg/kg	mass soil (g)	calc Pb #1	ICP Pb (mg/l)	solution amt (l)	% Relative Pb Bioaccessibility	
HER-2930-1		2473	1.00021	2.47	17.322	0.1	70	
HER-2930-2		2465	1.00036	2.47	17.062	0.1	69	
HER-2930-3		2534	1.00036	2.53	16.874	0.1	67	
HER-2930-1		2021	1.00021	2.02	17.322	0.1	86	Using average EPA value for bulk Pb
HER-2930-2		2021	1.00036	2.02	17.062	0.1	84	
HER-2930-3		2021	1.00036	2.02	16.874	0.1	83	
QA/QC								
HER-2930-3-AD					16.755			

3050

	As ppm	Pb ppm
HER-2930-1	2 57	2473
HER-2930-2	2 31	2465
HER-2930-3	2 63	2534
HER-2930-3-AD	4 16	2532
DL	5 00	1 00